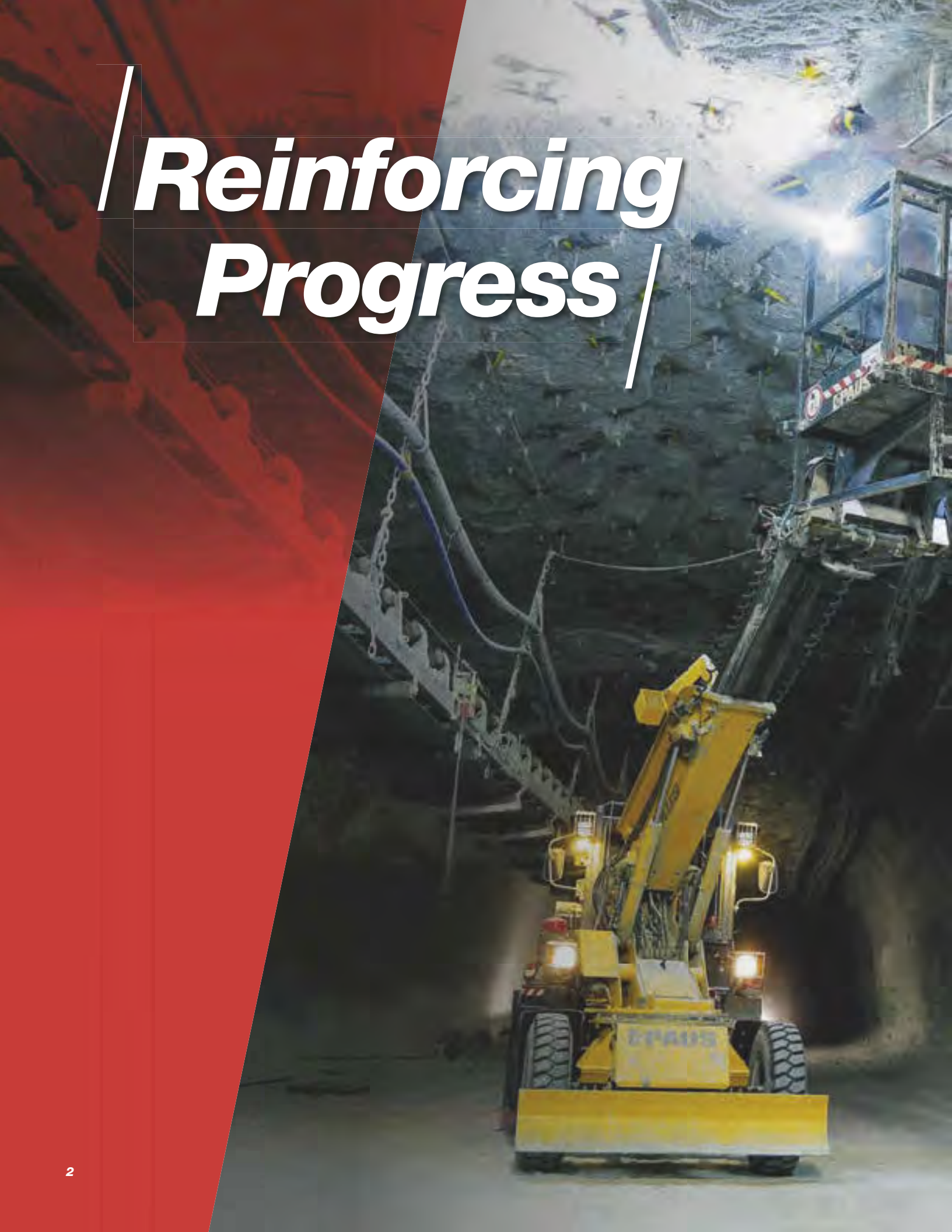
DSI UNDERGROUND
A SANDVIK COMPANY

Ground Control Solutions

Global Tunneling Edition

Reinforcing Progress



Contents

Preface

In 2013, DSI Underground (DSI) launched the first edition of this comprehensive technical product catalogue for the underground construction industry. Although our business world is changing and becoming more digitalized and interactive, the provision of sound technical background information is still key.

In recent years, DSI has been able to extend the business range through several acquisitions, thus adding new products and technologies to the portfolio. Since July 2021, DSI has been part of the Sandvik Mining and Rock Solutions business area, representing a significant step forward in supporting and shaping the underground construction industry.

Organic business growth and substantial in-house developments have led to the introduction of a series of innovative ground control solutions. This applies to the proven and well-known ALWAG Systems, as well as to a full product portfolio of DSI Inject chemical solutions. On the other side, longstanding support systems have not changed and will remain in use for decades to come.

Although this technical product catalogue is a global version, it also includes regional particularities regarding ground control solutions. Construction methodologies, installation processes, and material characteristics (such as steel grades) vary around the globe. More detailed information can therefore be found in local product brochures.

A global team of experienced, passionate, and committed underground experts, both internal and external, contributed to the new 2021 edition. On behalf of the DSI family, we would like to express our gratitude for all your contributions and support. Underground construction is not an individual piece of work, but rather represents the cooperation of a team of interested parties.

We at DSI are actively engaged in the global Tunneling community, contributing to a safe, efficient, and sustainable business.

Kind regards and Glueck Auf!

Wolfgang Dolsak
Karl Boehm

Progressing
Conventional Tunneling

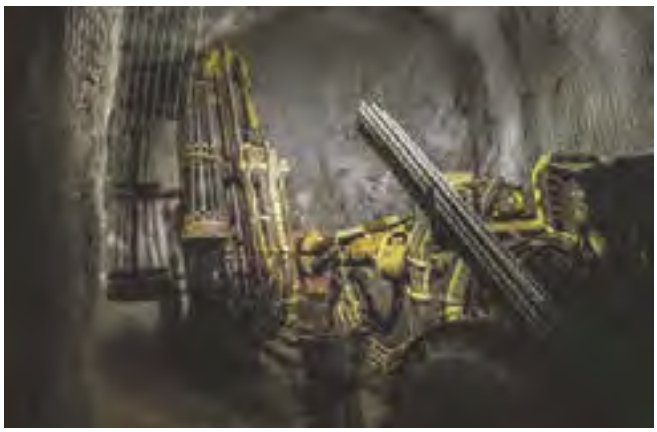
Working side by side you, we can solve any challenge, whatever the ground conditions

- **Trusted partner** of local and global contractors and tunneling specialists
- **Products and solutions** focusing on drill and blast operations
- **Countless projects worldwide:** rail and road tunnels, infrastructure tunnels, underground caverns, metro lines, and stations

Reinforcing
Mines

Working alongside you, our solutions cover every application to help drive your operations forward

- **Active** in all mining market segments: hard rock, soft rock, and coal mining
- **Trusted** by local and global miners and contractors
- **Global** supply chain allowing delivery of the right product on time, at the right cost, and in the right place



Our Values
Drive Our Philosophy Forward

Our philosophy looks forward, and is reflected in our values

- **Reliable** – Our people, products, and supply chain keep our customers' businesses moving forward efficiently
- **Responsible** – Upholding the very best in social, ethical, and environmental commitments to benefit all
- **Tenacious** – Whatever the challenge, we work tirelessly to find a way forward
- **Agile** – We respond quickly to every request, helping customers to plan forward with confidence

We Deliver
Reinforced Progress

We keep your businesses advancing with

- High-quality **products and systems**
- Flexible **world-class manufacturing**
- Efficient **supply chain**
- Driving **technology**
- Responsible **sustainability**
- Passionate **people**

About Us

Driving Underground Operations

DSI Underground is the world's leading supplier of ground control solutions for the mining and Tunneling industry. We are present in 70 countries and employ over 2 000 people, including engineers and technical specialists with in-depth experience of the underground industry.

With market-leading brands covering everything from bolting systems to injection chemicals and resin capsules, we reinforce tunnels and underground structures, helping our customers advance underground, and advance towards their objectives – faster and more efficiently than ever.

Crucially, while many suppliers simply offer standardized products, we apply our know-how to deliver customized solutions – created in collaboration with our customers, and modified and tailored to fulfill individual, specialized needs.

Accredited to ISO 9001:2015, with global manufacturing facilities and exhaustive in-house testing, we can meet even the most challenging lead times and order volumes, with the highest levels of quality and safety every time.

Meanwhile, with customized and truly international logistics capabilities, we can deliver reliably on time, ensuring continuous production and continuous uptime and operation around the clock.

And finally, with a presence in all key markets, our expert team is available with detailed recommendations and comprehensive advice, including on-site as well as remote installation supervision, training, and testing – all to solve the challenges of our customers and keep the underground business moving forward.

All together, we reinforce operations, teams, and capability, helping you advance into the earth – and into the future.

Reinforcing Progress

Mining and Tunneling provide a vital contribution to human progress.
As a specialist supplier to the industry, DSI Underground helps to reinforce this progress – for our customers and for the world.

Progress cost-effectively, with the world's leading ground support product range – from one source.

Progress safely, with tried-and-tested products that comply with all international standards.

Progress reliably, with a global supply chain that minimizes delays and downtime.

Progress efficiently, with new technology that improves productivity and performance.

And progress confidently, with the back-up and support of specialist engineers in your territory.

By reinforcing your tunnels, mines and underground structures, we safeguard the wellbeing of your people and help to improve efficiency. And in helping to solve the challenges of digitalization and the advent of Industry 4.0, we not only reinforce your operations, but help driving mines and tunnels forward, more effectively, to a successful future.

We Reinforce Progress.

Proven System Solutions

As a trusted partner to Tunneling contractors and construction companies, our products and systems have been used on countless projects worldwide. Wherever we work, our expertise and reliability add value to operations, helping to reinforce the progress of tunnels as well as the economic growth of countries and regions.

Our system solutions cover both excavation and ground support systems, including self-drilling bolts, the innovative AT – Pipe Umbrella System, as well as a wide range of injection chemicals. Supported by a dedicated team of engineers, we can solve every application challenge, whatever the ground conditions. Where required, we will also design and develop customized solutions or provide training and installation supervision.

Today, as cities go underground and projects become more ambitious, we are evolving our capability to support the Tunneling sector with new technologies. From injection and waterproofing systems to passive support, drainage drilling systems, and our pioneering DSI Hollow Bar System, we offer a complete range of solutions to keep your Tunneling operation moving forward efficiently – and all from one single supplier. Working side by side with you, we help to progress safely and sustainably.

Past, Present, and Future

Heritage

Our pioneering contributions to the Tunneling industry are based on two companies, which have become part of DSI. Commercial Shearing & Stamping Co based in Youngstown, Ohio (US) supplied steel liner plates as tunnel support since the 1920s. ALWAG Tunnelausbau Gesellschaft m.b.H. was founded as a system supplier for the European Tunneling industry in the 1980s and contributed significantly to the development of modern tunnel ground control systems.

DSI led pioneering and fundamental research in the field of ground control solutions for Tunneling. Commercial Shearing & Stamping Co, a predecessor firm of our North American Tunneling company, co-authored two of the most important publications in this field: *Rock Tunneling with Steel Supports* and *Earth Tunneling with Steel Supports*.

The development of state-of-the-art bolting and forepoling systems was made possible by the introduction of self-drilling installation technology. Subsequently, common standards of mechanized installation were established throughout the global Tunneling industry.
DSI played an important role in leading this development by the introduction of the AT-SYSTEM and ALWAG Systems (AT – Pipe Umbrella Support System and AT – Automation Unit) in 1998.

Today

Tunnel construction is one of the most difficult, challenging, and at the same time fascinating artwork in civil engineering. Modern tunnels are becoming longer and longer and often feature larger cross-sections. The fulfillment of strict environmental regulations, requirements for modern fire protection/ventilation, and continuous monitoring functions increase the demands on all partners involved in this ecosystem.

With proven and innovative system solutions, we support safe tunneling. Our global product and service portfolio includes bolts, injection and sealing systems, forepoling systems and passive support, as well as special support systems. Our products and systems are used in countless projects worldwide on all continents. Wherever we work, our expertise and reliability help to make tunneling safer, more economical, and more efficient. DSI provides a complete range of ground control solutions – all from a single source.

Outlook

In future, an increasing number of global infrastructure projects will lead to increased activity in underground construction. Surface building space becomes scarcer, while the relevance for public transport is increasing. Recently, significant technological advances have been made in digital technologies, offering a wide range of applications and reinforcing underground safety.
We have also invested heavily in this area to provide our customers with efficient, safe, and state-of-the-art solutions.

Our success is based on four important pillars.

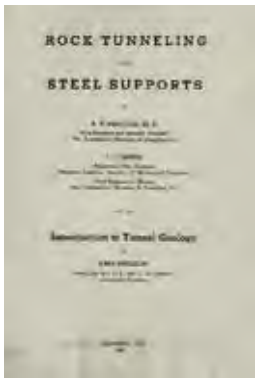
Trust – Trust takes time to build and requires expertise, transparency, and an agile, customer-focused commitment. We have more than 100 years of experience and rely on our global expertise with a presence in over 70 countries.

Long-term partnerships – Our focus on lifecycle costs and digital transformation strategies helps us to build and develop effective long-term relationships.
We do this by leveraging best global practices and digitalization with true local resources to provide the new face of supply chains (e-local).

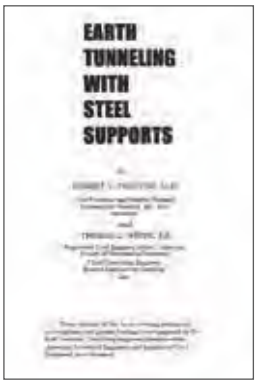
Socially sustainable – By working locally, we create jobs and invest in communities while helping to reduce emissions and transportation costs. We also use a wide range of digital technologies to support and improve operations in a sustainable way.

Digital transformation – Backed by a resilient digital ecosystem, we are developing new ways to support our customers. DSI is present digitally and remotely, with VR simulators to support the lifecycle of consumables and to manage increasing productivity and safety demands.

Rock Tunneling with Steel Supports (1946)



Earth Tunneling with Steel Supports (1977)



Arlberg Road Tunnel (1974)

ALWAG SYSTEMS *(1998)*

Project World Map

1 Metro Tunnel Project
Melbourne, Australia

2 Sydney Metro Pitt Street
Sydney, Australia

6 City Rail Link
Auckland, New Zealand

3 Nikachhu Hydropower Project
Trongsa, Bhutan

7 T219 & T225
Singapore, Malaysia

11 Chinatown Station
San Francisco, CA, USA

4 Central Kowloon Route
Hong Kong, China

8 Eglinton Crosstown LRT
Toronto, Canada

12 Tysons Corner, Dulles Corridor Metrorail Project
Vienna, VA, USA

4 C1103-Hong Kong
Hong Kong, China

9 John Hart Generating Station Replacement Project
Campbell River, BC, Canada

13 Drumanard Tunnel
Louisville, KY, USA

15 Semmering Base Tunnel
Spital am Semmering, Austria

17 Koralm Tunnel
Lavant Valley, Austria

5 Rohtang Tunnel
Himachal Pradesh, India

10 Edmonton LRT
Edmonton, Canada

14 Moglicë Hydro Power Plant
Moglicë, Albania

16 A26 Motorway
Linz, Austria

18 Brenner Base Tunnel
Innsbruck, Austria

29 Transolímpica Tunnel
Rio de Janeiro, Brasil

30 Alto Maipo Hydroelectric Power Plant
Maipo Valley, Chile

31 AVO I Highway
Santiago, Chile

19 ATCOST21
Stuttgart, Germany

22 Grand Paris Express
Paris, France

24 HS2
London, Great Britain

31 Extension Metro Line 3
Santiago, Chile

20 Arlinger Tunnel
Pforzheim, Germany

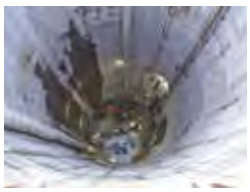
23 Turin-Lyon High-Speed Railway
Saint-Michel-de-Maurienne, France

25 Galleria Floronzo
Pflaurenz, Italy

27 Tunnel Pekel
Žalec, Slovenia

32 Túnel del Toyo
Giraldo, Colombia

21 Metro Algiers
Algiers, Algeria



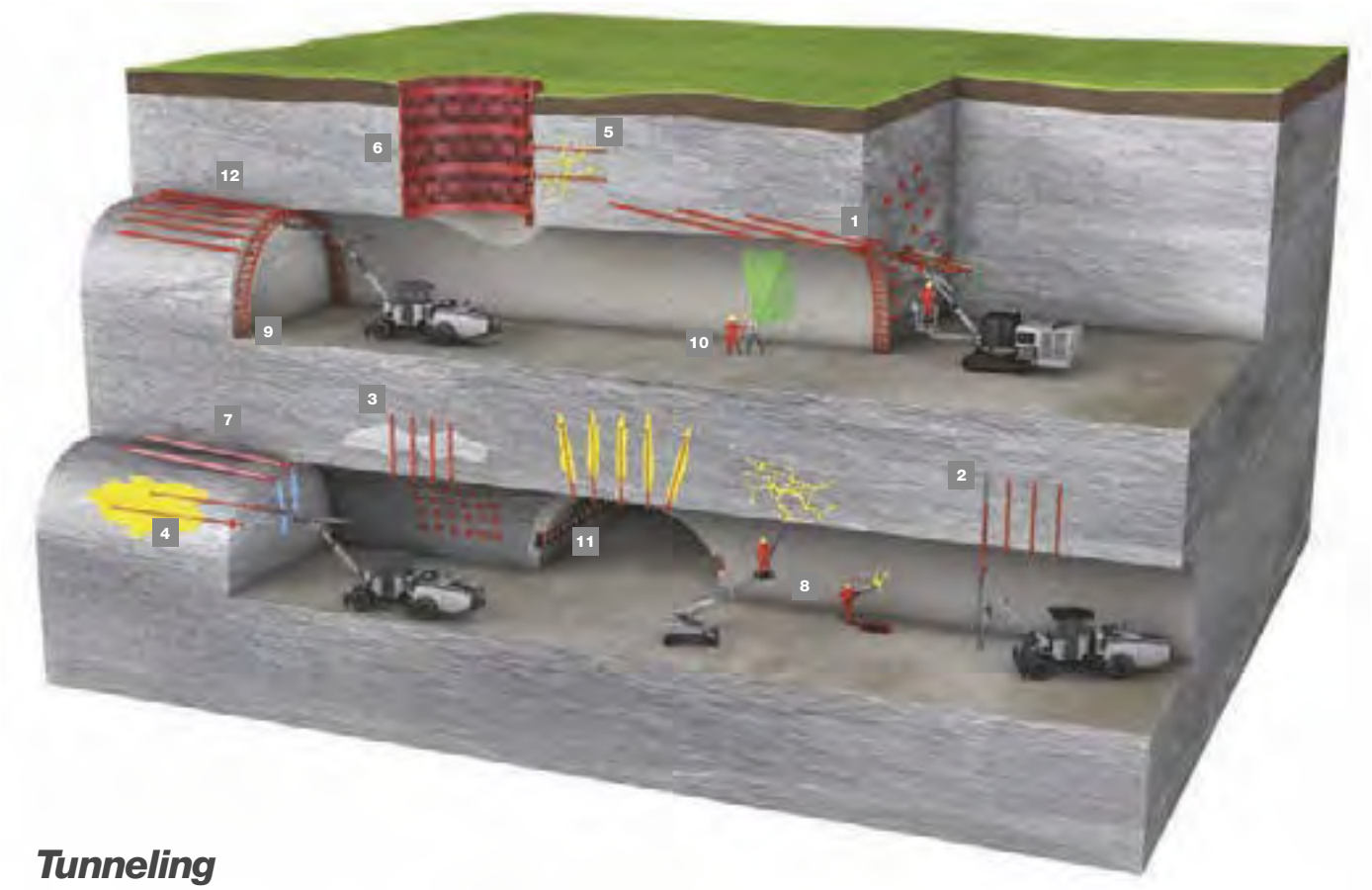
24 Thames Tideway
London, Great Britain

26 Express Road S1
Węgierska Górka, Poland

28 Gautrain High Speed Train
Johannesburg, South Africa

33 Tren Interurbano
Mexico City, Mexico

System Solutions

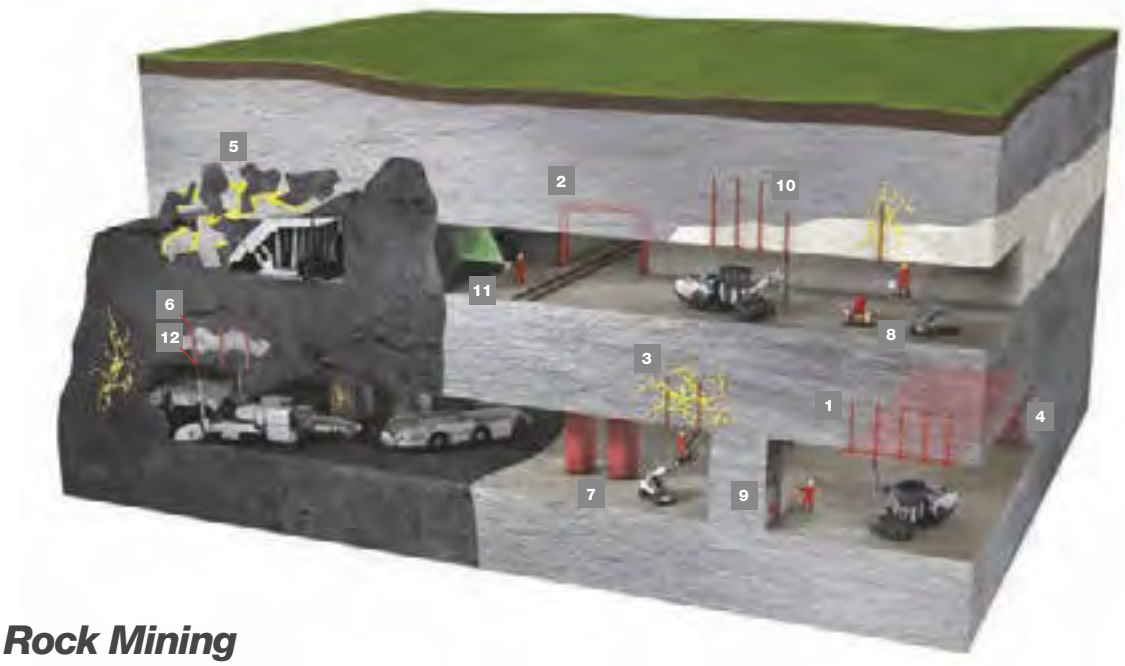


Tunneling

1. AT – Pipe Umbrella System & Automation Unit
2. OMEGA-BOLT® Expandable Friction Bolts
3. SN-Bolts and FASLOC® Resin Cartridges
4. Mineral Bolt Silicate Bolting Resin and GRP Bolts
5. DSI Hollow Bar System
6. Liner Plates & Steel Ribs
7. AT – Drainage System
8. DSI Inject Systems
9. Lattice Girders
10. Monitoring Systems
11. LSC™ Elements
12. AT – TUBESPILE™

Hard Rock Mining

1. Specialty Grouts & DSI Hollow Bar System
2. OMEGA-BOLT® Expandable Friction Bolts
3. Strata Injection Chemicals & Foams
4. Steel Ribs & BULLFLEX® Roof Support Backfilling
5. Friction Stabilizer Bolts & Mesh
6. FASLOC® Resin Cartridges
7. BULLFLEX® Support Pillars
8. Mineral Bolt Silicate Bolting Resin
9. Energy-Absorbing Bolts
10. Monitoring Systems
11. Cable Bolts
12. Rebar Bolts



Soft Rock Mining

1. OMEGA-BOLT® Expandable Friction Bolts
2. Steel Ribs & BULLFLEX® Roof Support Backfilling
3. Strata Injection Chemicals & GRP Bolts
4. Friction Stabilizer Bolts & Mesh
5. Mine Fill Cavity Filling Foam
6. FASLOC® Resin Cartridges
7. BULLFLEX® Support Pillars
8. Mineral Bolt Silicate Bolting Resin
9. Energy-Absorbing Bolts
10. DSI Hollow Bar System
11. Monitoring Systems
12. Rebar Bolts

Manufacturing Competence

DSI Hollow Bar System

Facility

- Global competence center DSI Hollow Bar System in Pasching, Austria
  - Production of hollow bars based on the DSI proprietary cold rolling technology
  - Prime safety due to a completely enclosed and fully automated production line
  - Development, testing, and sourcing of system accessories

Portfolio

- DSI Hollow Bar System
  - Series R32
  - Series R38
  - Series R51
  - Series T76
- Fully threaded bars (type CR)
- System accessories
  - Central high-bay warehouse system

Figures

- Total annual capacity
  - Reference hollow bar R32 with 4 [kg/m]
  - Up to 5,6 Mio. [m] / up to 22 500 [t]
- Cold rolling speed
  - 13 [m/min]
- Quality assurance
  - Key performance tracking
  - DSI production system based on TPS and lean management

AT – Pipe Umbrella System

Facility

- DSI Underground MEROL: central production facility for squeezed connection type pipe umbrella pipes
- TUBE Tirol
  - R&D center
  - Manufacturing starter units (drill bits)
  - Assembly and service
    AT – Automation Unit

Portfolio

- AT – Pipe Umbrella System
  - AT – 89
  - AT – 114
  - AT – 139
- AT – Drainage System
- AT – GRP Injection System
- AT – Squeezing and Automation Unit

Figures

- Weekly capacity of up to 100 [t] squeezed connection pipe umbrella pipes
- Fully mechanized drilling station for pipe umbrella injection holes
- CNC workshop: CTX BETA 1250 TC 4A and CTX BETA 800 4A

OMEGA-BOLT®

Facility

- Global center OMEGA-BOLT® manufacturing in Stalowa Wola, Poland
- Production of OMEGA-BOLT® profiles based on cold rolling technology
- Robotic, fully automated welding lines
- Integrated QA laboratory

Portfolio

- OMEGA-BOLT® Expandable Friction Bolts
  - EFB-120
  - EFB-160
  - EFB-200
  - EFB-240
  - EFB-120+
  - EFB-240+
- Connectable OMEGA-BOLT® 240/240+
- Complete product range of flat and domed plates
- Pneumatic and electric high-pressure inflation pumps

Figures

- Monthly production capacity: EFB-120, L = 2,1 [m]: 120 000 [pcs]
- Total monthly consumption of steel: approx. 1 200 [t]
- Cold rolling speed EFB-120: 30 [m/min]
- 100% quality assurance by non-destructive testing (NDT)

Injection Chemicals and Resin Cartridges

Facility

- Global competence center for injection chemicals and resin cartridges
- Factory in Poland, Katowice region
  - High-tech production technology enables maximum output and efficiency
  - Fully automated production lines for injection chemicals (5) and resin cartridges (2)
  - Tailor-made production program upon request
- R&D structures covering the entire product portfolio
- Integrated field-testing facility (test mine)

Portfolio

- Injection resins
  - Polyurethane
  - Silicate
  - Acrylic
  - Phenolic
- Resin cartridges
  - Single and duo speed
  - Water or oil-based
  - Tunneling and mining versions
  - For manual and mechanized installation
- Injection equipment and accessories

Figures

- Total annual capacity
  - Injection resin: 20 000 [t]
  - Resin cartridges: 16 000 000 [pcs]
- Quality assurance
  - Integrated quality control system: raw materials and finished products
  - ISO 9001: 2015 and ISO 14001: 2015 certified

Liner Plates and Steel Ribs

Facility

- Competence center passive ground support systems in Louisville, US-KY
  - Stamped steel liner plates
  - Steel ribs and shaft rings
  - Modular lattice girder systems
- 70 000 square foot engineering and production facility

Portfolio

- Beam forming up to 27" (HEB 700)
- Steel liner plates in thicknesses from 12 gage up to 3/8"
- Spatial 3-, 4-, 6-, and 8-bar girder systems
- Modular support systems for break-outs (adits)

Figures

- Total annual capacity greater than 20 000 tons of steel
- Average of 191 engineering submittals per year
- Quality assurance
  - ISO 9001: 2015
  - Key performance tracking
  - Lean management and TPS

Combination Bolts

Facility

- Bennetts Green, AU-NSW: 20 113 [m²] total site area
- Rock bolt solid bar manufacturing: fine thread rolling
- Precision machining
  - CNC milling, turning, and EDM
- Brisbane (QLD) manufacturing site: galvanization
- Testing laboratory with a tensile testing capacity up to 100 [t]

Portfolio

- Combination type bolts
  - CT400
  - CT26WR
- Cable bolts
  - 15,2 [mm], 17,8 [mm], 21,8 [mm], 23,5 [mm], 28 [mm]
  - Standard and DCP versions
- Surface support plates and washers

Figures

- Annual solid bar production capacity: 25 000 [t] (Bennetts Green plant only)
- Heavy stamping capacity up to 300 [t] at 40 parts per minute
- ISO 9001: 2015

Quality

Introduction

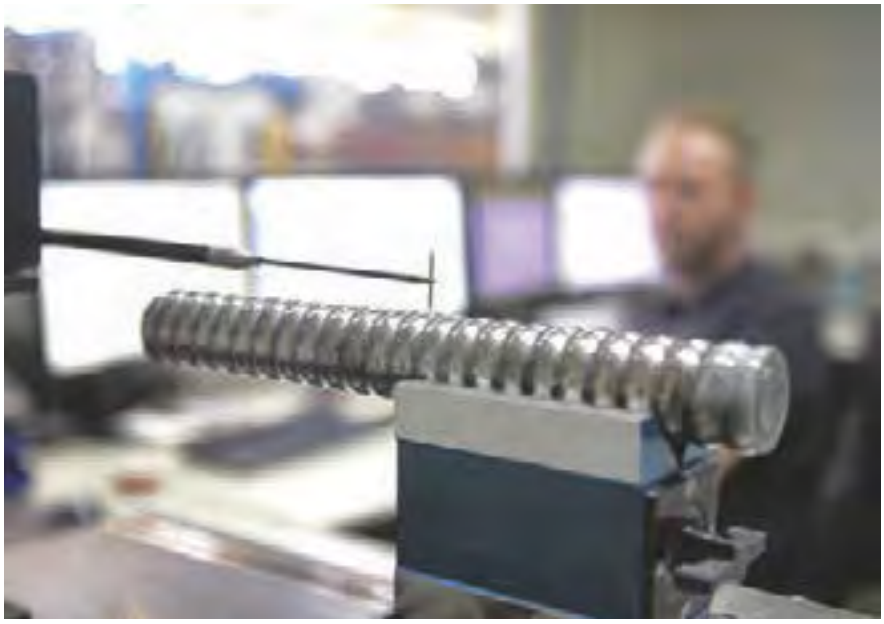
At DSI Underground, quality is our business and is central to our daily actions. In order to guarantee the implementation of quality-related requirements in all areas from development to application, our production plants are certified in accordance with ISO 9001.
Regular internal and external audits serve to examine and actively promote the development of the quality management system.

Quality is not an aim, but a continuous process, which is also one of the main principles of Total Quality Management (TQM). We are committed to TQM on a global scale and work in accordance with its three basic principles:

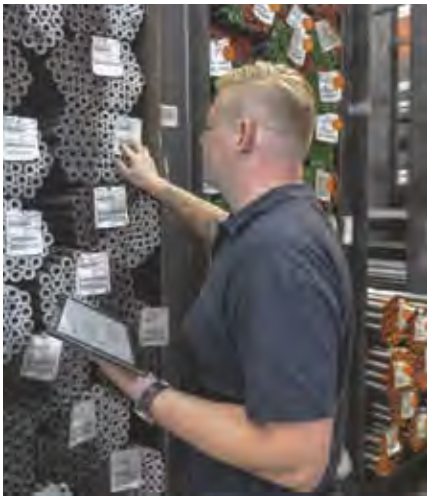
- Total: integration of all employees contributing to the manufacturing of products or systems into the QM process
- Quality: continuous orientation of all company activities toward customer expectations
- Management: responsibility and role-modeling by highest-level management based on participative and team-oriented leadership

Quality assurance requires a skilled team of experienced experts and appropriate instruments and equipment.
The Tunneling competence center of DSI Underground Austria is equipped with the following major devices:

- High-capacity horizontal tensile testing machine type DSI Hotz 3000/250 (max. 3 000 [kN], sample length 3 [m])
- Vertical tensile testing machine type Zwick/Roell Z1200 (max. 1 200 [kN])
- Universal hardness tester type Zwick/Roell ZHU250CL (HRC, HV, HB)
- Surface profile measurement instrument type Marsurf PCV (accuracy 0,005 to 0,020)
- Wide range of field equipment for anchor tensioning and pull testing



DSI Underground also cooperates with university research institutions and government testing facilities, to be able to evaluate ground control systems before, during, and after the construction phase. To support quality control on-site, customized quality control tools for inspection of various products can be provided upon request.



Research & Development

As the market leader, DSI Underground is present in all global underground regions, delivering customized solutions to clients around the world.
DSI Underground's motto is "learning from the best at all levels" to advance further developments and innovations according to customer requirements. The business environment should be a fruitful basis for cooperation, responsibility, challenge, creativity, and commitment of employees and staff.

DSI Underground's willingness to change keeps the company at the cutting edge of social, technological, and economic developments. Therefore, DSI Underground pursues a strategy of exploration and exploitation innovation and sustainable human resource development to remain agile for future challenges.

- Market knowledge
  - Very precise knowledge of the market in order to adapt products or services to market requirements or to address latent customer wishes
  - Customers are integrated into the innovation process
- Strategic partners
  - Collaborations with external partners: strategic alliances, network partners, universities, and research facilities
- Radical innovation culture
  - Core values are risk orientation, proactivity, and a certain degree of fault tolerance
- Internal networks
  - Expanding internal networks enable communication between departments or locations to implement and develop new trends and ideas
  - DSI Underground promotes simple communication channels and an open communication culture – global teams

Innovation Strategy

Exploitation – Improvement and Optimization (Management Focus)

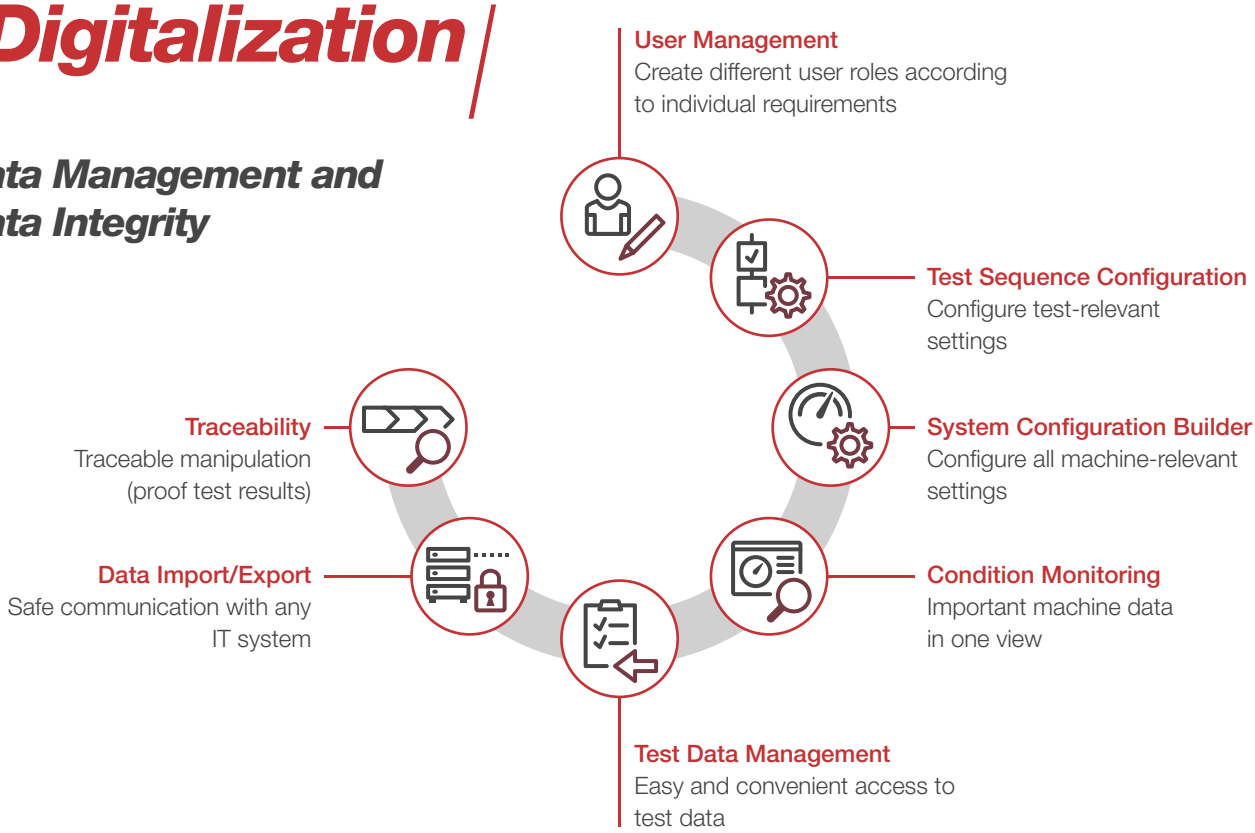
- Best practice
  - Increase efficiency through learning processes
- Lean management
  - Optimization of resource utilization
- Quality management (ISO 9001)
  - Creation of clear procedures and stable structures, tasks, and responsibilities

Exploration – Experimentation and Innovation (Leadership Focus)

- Agile project management
  - Flexible processes harness change for the customer's competitive advantage
- Positive error culture
  - Employees learn from mistakes and avoid repeating them, which saves time and promotes knowledge
- Open innovation
  - Opening up of the innovation process around the active, strategic use of customers and partners to increase potential

Digitalization

Data Management and Data Integrity



Digital Bolt

Mechanized Installation

Introduction

In cooperation with world-leading original equipment manufacturers for Tunneling, DSI Underground can develop customized attachment units which enable a fully mechanized installation of ground control systems.
Probably the most recognized system on the market is the so-called “AT – Automation Unit”, which is used for installation of the AT – Pipe Umbrella System.

Another important area of mechanization is bolt installation. Here, the DSI Hollow Bar System is the most popular bolt when it comes to self-drilling installation. Hollow bar systems were developed in the 1980s for use in combination with standard tunnel drill jumbos and can either be installed semi-mechanized or fully mechanized with a bolt magazine and grouting boom.

Recent ground-breaking developments in Tunneling have taken place in Australia, where bolts may only be installed fully mechanized, i.e. all installation steps are mechanized and controlled manually. The most common ones are combination type rebar bolts, a combination of a mechanical anchor and a fully grouted bolt. Another special fully mechanized bolt type which has recently been introduced is a combination cable bolt.

DSI Underground offers unique combined expertise in the development of mechanized installation concepts for both supporting elements (e.g. bolts) and bonding media (e.g. resin).

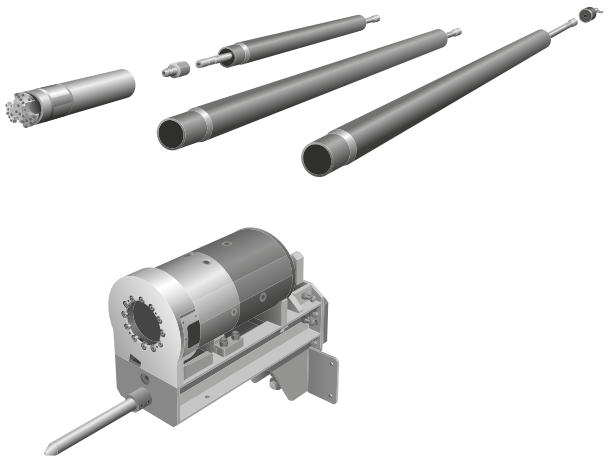
Requirements

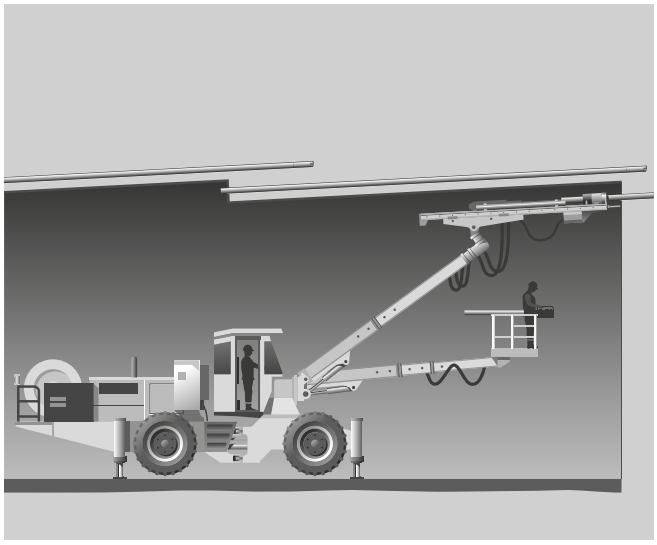
- Multi-purpose and versatile
- Simple handling
- Customized design
- Minimal weight of attachment units
- Remote-controlled manipulation
- Easy-to-maintain interfaces

Main Advantages

- Reduction of equipment in operation
- Lower manpower requirements
- Enhanced quality control
- Increased occupational safety
- Simplified work sequence and cycle time savings

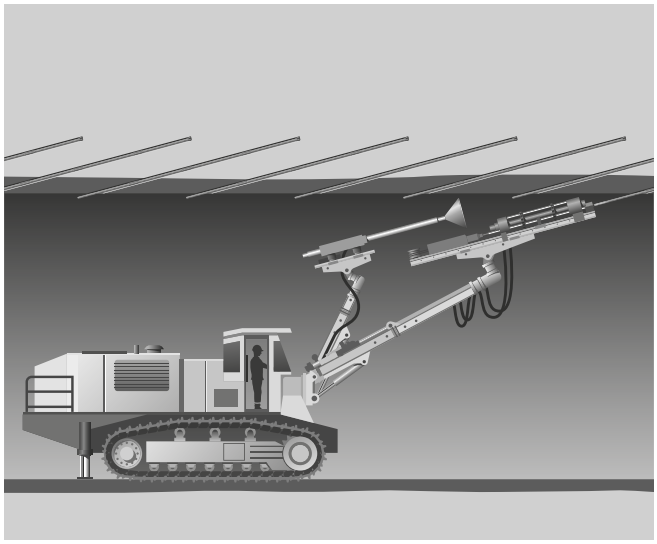
AT – Pipe Umbrella System



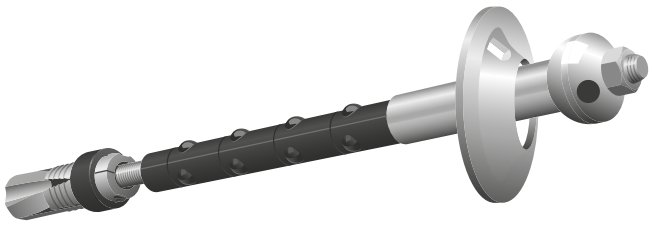


DSI Hollow Bar System

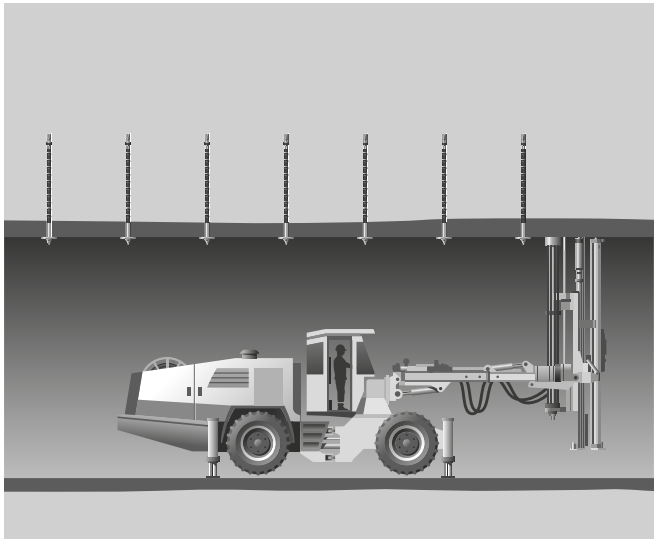
Operational Sequence	Semi-Mechanized	Fully Mechanized
Borehole drilling	Jumbo	Jumbo
Insertion	During drilling	During drilling
Extension (couplings)	Manual	Magazine
Post-grouting	Manual (loading basket)	Grouting boom
Tensioning	–	–



Combination Type Bolts

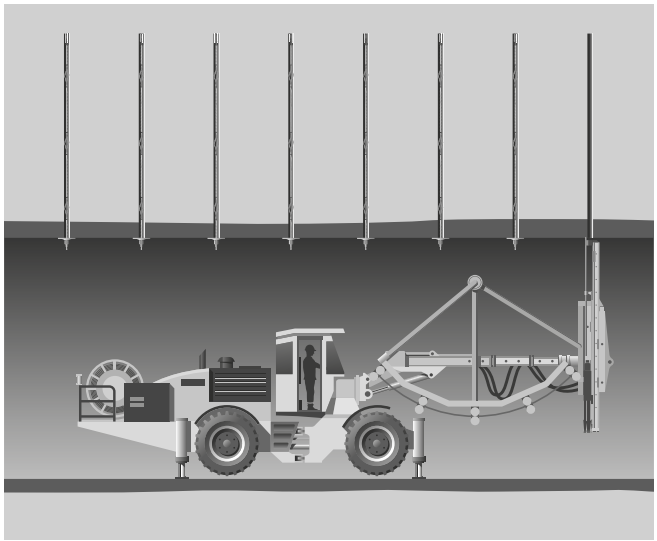


Operational Sequence	Semi-Mechanized	Fully Mechanized
Borehole drilling	Jumbo	Drilling feed
Bolt insertion	Manual (loading basket)	Bolting feed
Tensioning		Bolting feed
Post-grouting		Grouting boom



Cable Bolts

Operational Sequence	Conventional	Mechanized
Borehole drilling	Jumbo	Drilling feed
Bolt insertion	Manual (loading basket)	Pendular boom
Tensioning		Anchoring tube
Post-grouting		Grouting boom

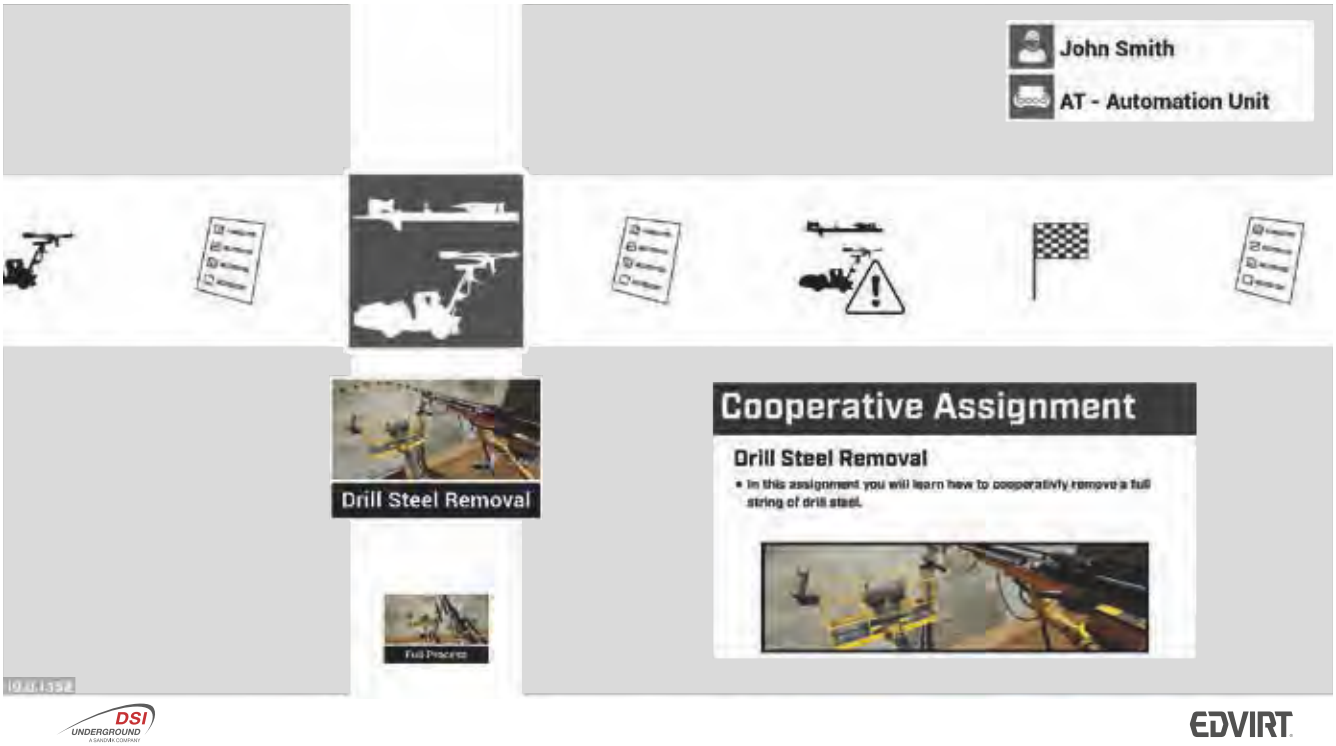


Virtual Reality

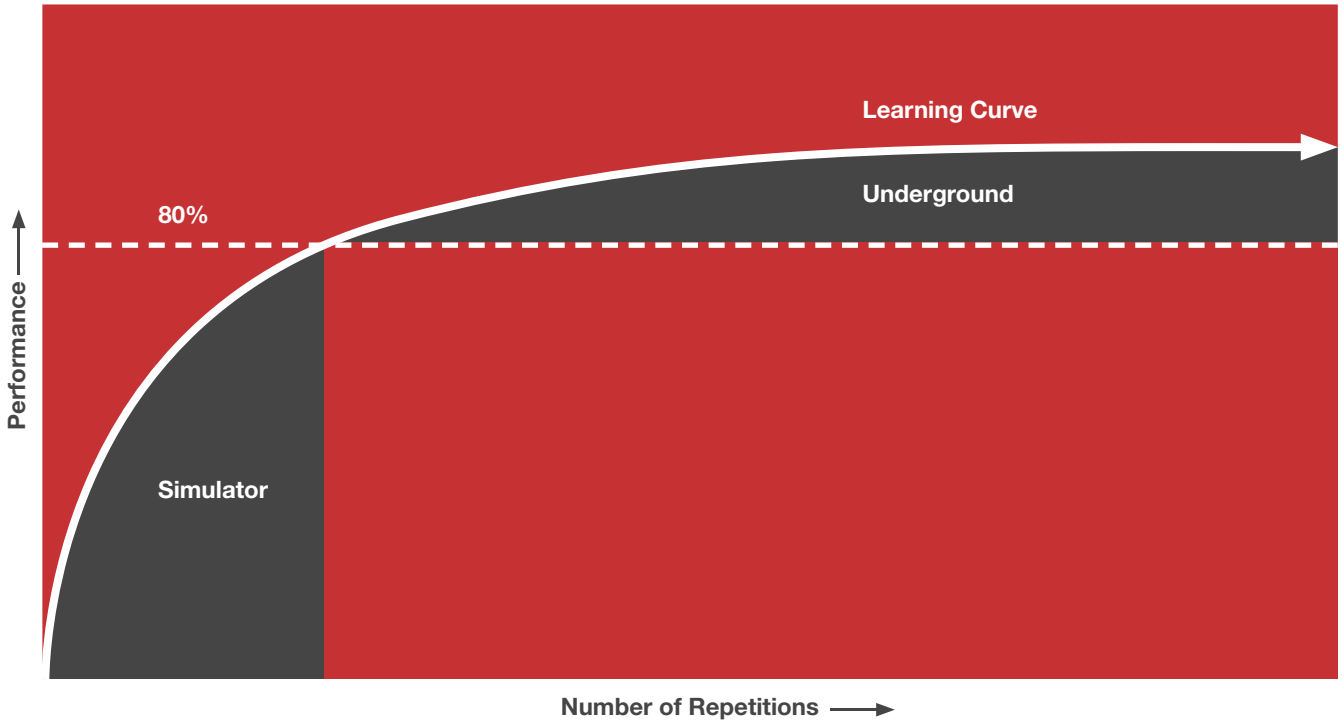
Increased Safety	*Industry-leading virtual training before commencement in construction*
Enhanced Quality	*Virtual reality based simulators increase the performance of both novice and experienced operators, powered by* EDVIRT
Leveraged Costs	*Simulators and training courses are designed to reduce costs and improve machine utilization*

Introduction

- The first virtual reality (VR) training simulator for pipe umbrella installation
- State-of-the-art training for both drill jumbo and basket operators
- Highly realistic and authentic simulation process
- Scenario-based simulator practice in VR combined with extensive theory modules
- Training of operators in a safe environment without risking accidents or machine damage
- Remote support during mounting, commissioning, maintenance, and operation

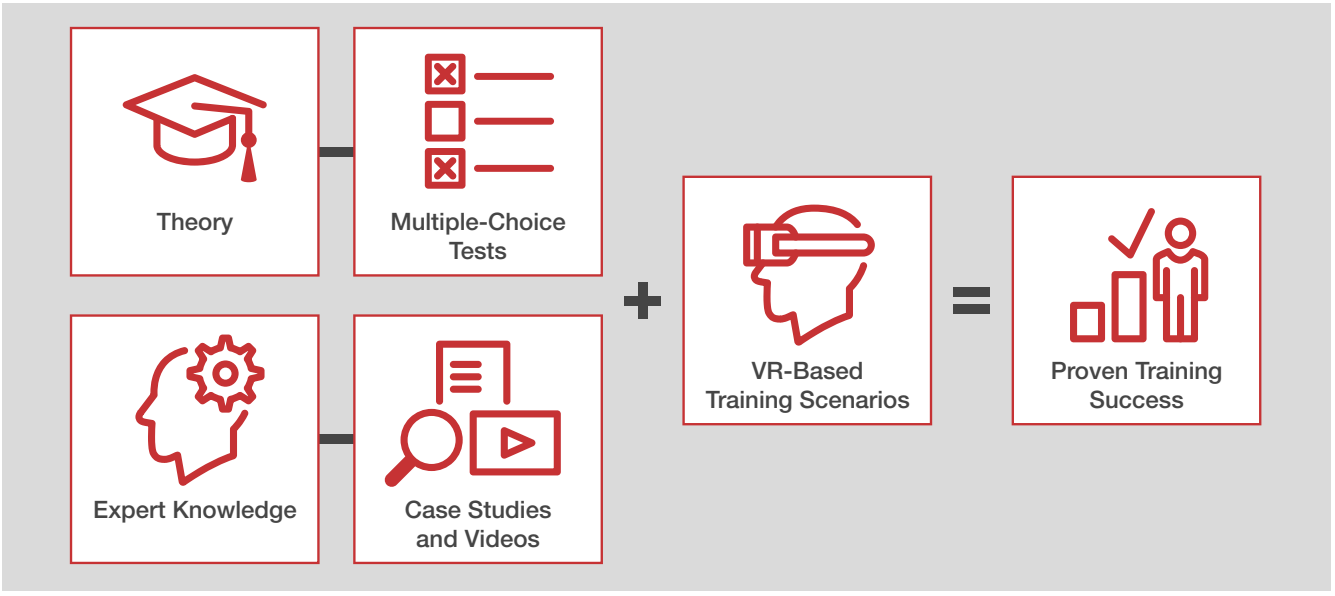


Reinforcing Competence



Training Program

- Modular training and assessments with user-based performance analysis
- Integrated video case studies illustrate best underground practices
- Bolstered by contributions from global industry experts
- Comprehensive personalized and certified training courses
- Multi-user simulator training where two operators and a trainer can jointly conduct scenario-based VR training
- Training can be delivered in person or remotely
- Customized project-based consulting



Bolts

Contents

Introduction

Underground excavation is typically supported by radial bolts, reinforced shotcrete, and if required by steel arches. While shotcrete lining provides passive support, radial bolts stabilize and reinforce the surrounding ground and create a so-called supporting arch in this area – the main intention is to increase the capacity of the ground regarding shear load and tension. Bolts are an essential part of the primary support in tunnel construction and must also be selected with the appropriate diligence to be optimally suited for expected ground conditions.

Bolts are either installed self-drilling, where drilling and bolt installation takes place simultaneously, or in pre-drilled boreholes. Once installed, bolts can be activated by pre-tensioning, tensing at the bolt head, or they can be left un-tensioned and are furtheron activated by ground deformations. Typically, bolts are activated and used as tension elements. However, in ground conditions where the dominant failure is block failure, bolts may get loaded by shear. In these cases, the cross-sectional area as well as the material properties are relevant selection criteria.

The most common bolt material is steel, whereas various steel grades are used depending on the bolt type. Governing factors for selection of a steel grade are forming capacity, a defined load-deformation behavior, and cost effectiveness. Steel tendons have various shapes, depending on bolt type and application. Typical bolt geometries are ribbed or round bars, threaded hollow bars (tubes), profiles, cables, or combinations of before-mentioned shapes. Alternatively, glass fiber reinforced plastic, with fibers as principal stress-bearing constituent which are embedded in a polymeric matrix (hereinafter referred to as GRP), is another bolt material used for different applications. State-of-the-art GRP systems consist of thermosetting resins and glass fibers.
Bonding agents are required for the installation of continuous or partially bonded bolts and establish the load transfer between borehole wall and tendon. There are two common types, cementitious grouts or injection resins. Bonding agents can either be applied in bulk or cartridge form.
Further information can be found in the respective catalogue section.

Bolt classification is based on the respective load transfer mechanism:

- Discrete mechanically anchored: load transfer at two discrete points, namely the bolt head and the anchorage point.
- Continuous bonded: load transfer from a reinforcement element (tendon) inside a borehole bonded by a bonding agent that fills the annulus between the bolt and the borehole wall over the entire length of the tendon.
- Continuous friction: friction resistance to sliding is generated by a radial force against the borehole wall over the entire length of the bolt.
- Combinations of above-mentioned systems and other: in case of squeezing ground, swelling ground, or rock bursts, use of bolts with an enhanced energy absorbing ability is required. Further information can be found in the respective catalogue section.

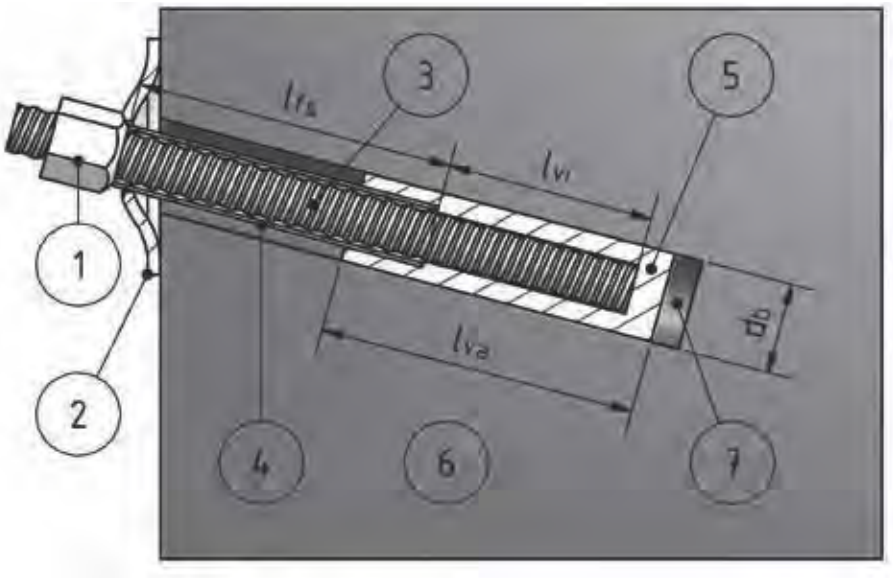
Source: ITAtech Activity Group Support (2018, work in progress)

System Components

Main system components of a bolt are as follows:

- Tendon: load-bearing element of a bolt which transmits tensile load along the axis of the bolt. Typically, it is a solid or hollow bar, but other shapes of cross sections (profiles) are possible as well. The surface can be smooth, structured (threads, ribs, etc.), or feature discrete anchorage points.
- Bolt head: assembly which typically consists of a plate and a fastening element attached to the near end of the tendon.
- Coupling: connects tendon sections to achieve the required bolt length.
- Expansion shell (not shown below): anchorage element connected to the tendon. They are mounted at the far end of the tendon and expand via a leaf-and-wedge system.
- Bonding agent: material to fill the annulus between bolt and borehole wall with a certain bonding strength to transfer load.

The following illustration shows an exemplary assembly of a bolt system in general accordance with DIN 21521-1 (1993).



1 Nut
2 Plate
3 Tendon
4 Sleeve
5 Bonding Agent
6 Ground
7 Borehole
l_{fs} Free Length
l_{vi} Inner Bond Length
l_{va} Outer Bond Length
d_b Borehole Diameter

Source: Kainrath & Dolsak (2008)

Bolt Selection and Classification

There is no bolt system covering all demands and therefore decision criteria are necessary to define the most suitable bolt type(s) at both the design and the construction stage. This requires knowledge about various characteristics of bolt types, their installation methods, areas of application, and activation modes.

Main selection criteria are:

- Borehole conditions: stable, unstable, or water-bearing
- Bolt length: uncoupled or coupled systems (extension required)
- Activation time: immediate load-bearing capacity or after curing of the bonding agent
- Time consumption: pre-drilling (conventional) or self-drilling installation, number of installation steps required
- Degree of mechanization: manual, semi-mechanized, or fully mechanized installation
- Service life, economic impact, and total cost of ownership
- Safety, environment, and resistance to vibrations

The classification presented in this catalogue is based on the load transfer mechanism and presented in the following order:

- Continuous bonding
  - DSI (self-drilling) Hollow Bar System
  - SN-Bolts (fully grouted rebar bolts)
  - GRP bolts
  - Cable bolts
- Continuous friction
  - Friction stabilizers
  - OMEGA-BOLT® water expandable friction bolts
- Discrete mechanical anchorage
  - Mechanical anchors (expansion shell bolts)
- Energy-absorbing bolts
- Combination type bolts

Source: ITAtech Activity Group Support (2018, work in progress)

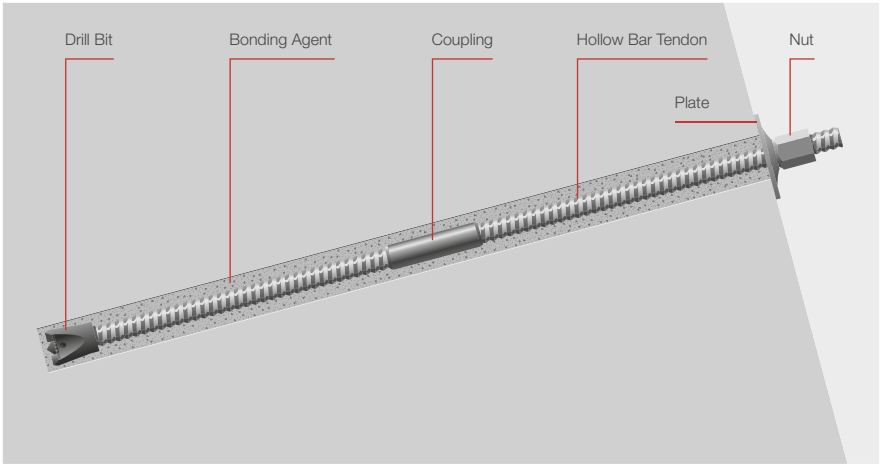
DSI (Self-Drilling) Hollow Bar System

The DSI Hollow Bar System is installed self-drilling, where borehole drilling and bolt installation takes places simultaneously. It is the preferable system for unstable borehole conditions and features a fast, safe, and simple installation procedure. Hollow bars are installed with a bonding agent in bulk form, either cementitious grout or injection bolting resin. Activation takes place via excavation induced deformations.

DSI Hollow Bars provide reliable support in all ground conditions, the self-drilling installation process ensures optimized cycle times. The bolt can be extended during installation using couplings and is perfectly suited for installation in unstable boreholes. Additional measures are required to fix the bolt in vertical orientation after installation, possible limitations are water carrying boreholes.

Main applications are:

- Radial bolting
- Stabilization of tunnel portals, trenches, and cut-and-cover areas
- Face stabilization
- Foot piles and rib bolting
- Injection works

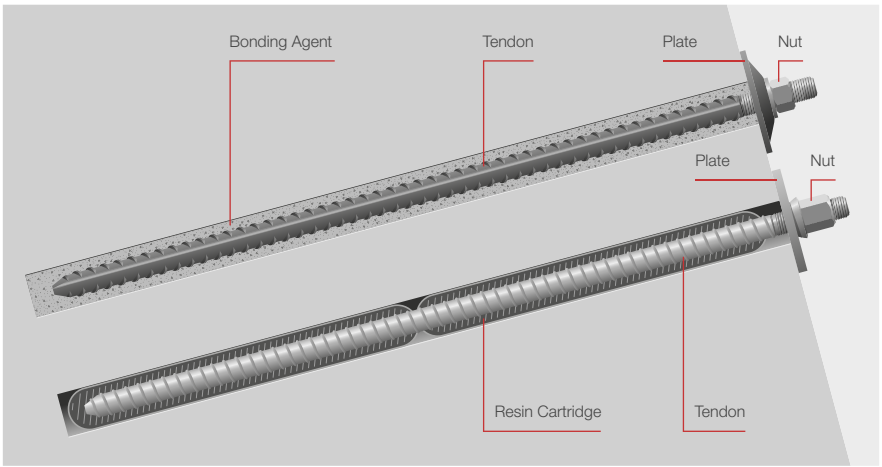


SN-Bolts (Fully Grouted Rebar Bolts)

SN-Bolts are the most common type of bolts used in Tunneling. They increase the self-supporting ability of the ground and limit loosening of blocks as well as shear displacements. Furthermore, the frictional force between individual ground layers is increased.

All SN-Bolts are fully grouted over the entire length and are usually installed un-tensioned. Cementitious or resin-based grouts are used as bonding media between borehole wall and tendon. They can also be tensioned using an end-anchorage consisting of fast setting resin cartridges. Installation takes place into pre-drilled boreholes and SN-Bolts are activated by excavation induced deformations.

SN-Bolts provide reliable support in various ground conditions and are a cost effective, field-proven, and standardized system. However, installation is possible in stable boreholes only, there is no possibility of self-drilling installation. Bolt length is limited to available space in the tunnel, and additional measures are required to fix them in vertical orientation. Sometimes, full encapsulation is difficult to check and maintain constant, also possible limitations in water carrying boreholes exist. Proper installation of SN-Bolts needs skilled and experienced underground personnel.



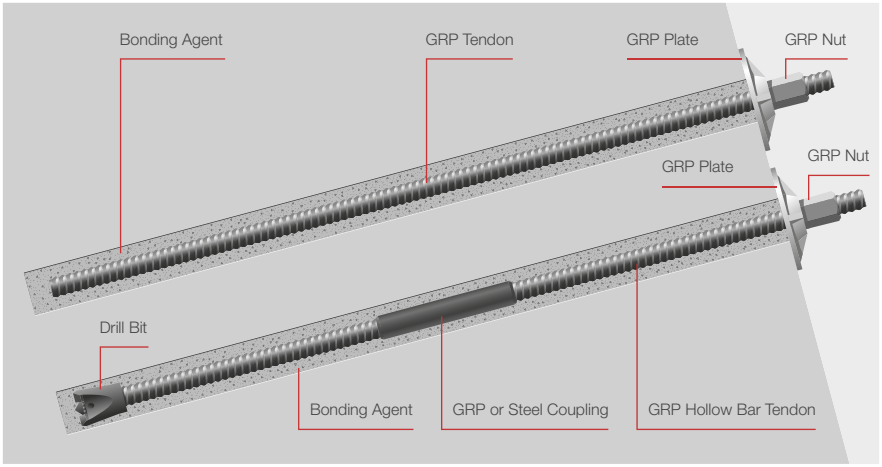
GRP Bolts

GRP is a brittle material with a high tensile strength, which shows an elastic behavior up to failure. Further characteristics are a low unit weight, are easy to cut, and exhibit low electrical conductivity. They also have a high resistance to aggressive environments. GRP bolts are also available as hollow bars, however self-drilling installation is limited.

Additional measures are required to fix the bolts in vertical orientation, the load-bearing capacity defined by the performance of nuts and couplings is general lower. Besides the brittle behavior, low compression resistance is another limiting factor.

GRP bolts are commonly used for:

- Injection lances
- Face bolts
- Cuttable or temporary (removable) bolts
- Mechanized Tunneling (soft eyes)

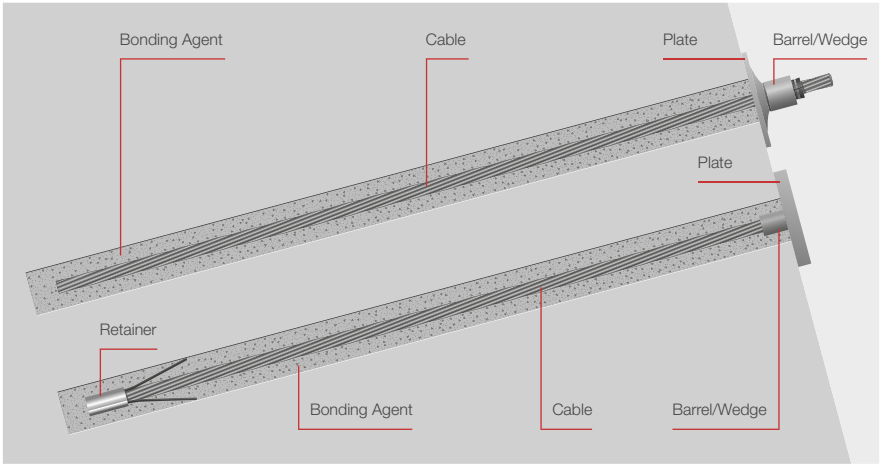


Cable Bolts

Fully grouted cable bolts are commonly used for bolting applications in limited space conditions. They are a high-strength ground control element for critical underground sections.

Main applications for cable bolts are:

- Supplementary bolting
- Reinforcement of machine or utility caverns
- Large-scale non-entry excavations
- Intersections and drawpoints



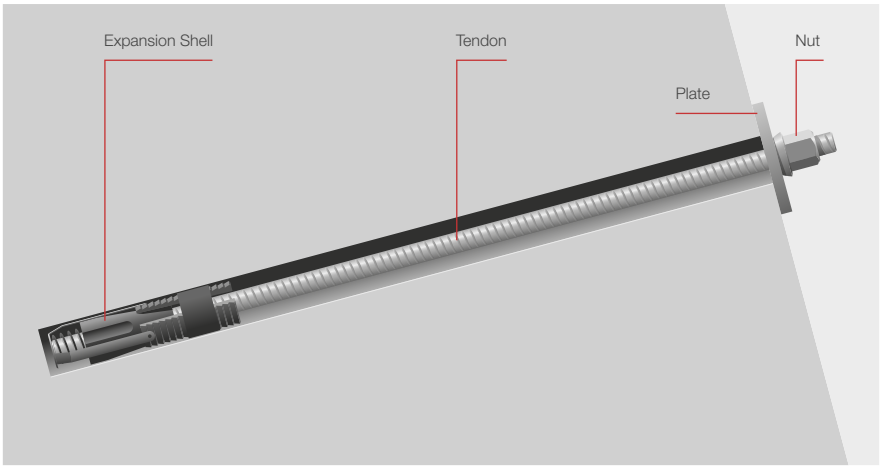
Mechanical Anchors (Expansion Shell Bolts)

Expansion shell bolts are used in blocky (hard) rock conditions to inhibit movement of kinematically free blocks. Mechanical anchorage is transferred by an expansion shell onto the borehole wall, a variable free length enables pre-tensioning and thus an active force transmission. Bolt activation is accomplished by tensioning of the nut. The load-bearing capacity of a mechanical anchor is mainly determined by the stability of the borehole (ground characteristics), the amount of pre-tensioning, and the design of the expansion shell.

Mechanical anchors provide reliable support in hard ground (rock) conditions and an immediate load-bearing capacity after installation. They can also be used in water-carrying boreholes. However, their application in soft ground conditions is limited and installation is possible in stable boreholes only. Load transmission of load between expansion shell and borehole wall is limited to a defined, short anchorage length.

DSI Solid Bar System mechanical anchors and mechanical rebar anchors are well established systems with a free length. Main fields of application are:

- Systematic anchoring for underground applications
- Doweling of layers in the hanging wall
- Utility hangers

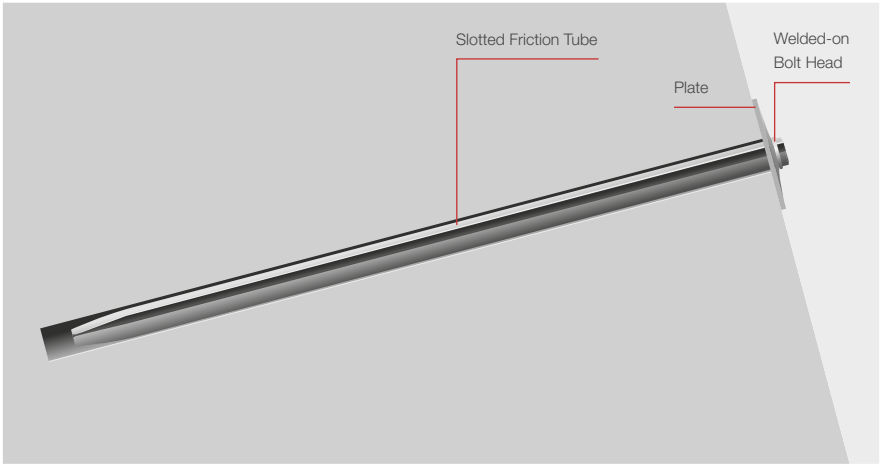


Friction Stabilizers

Friction stabilizer type bolts are commonly used in underground mining, there is also a self-drilling friction bolt version available for Tunneling (POWER SET). The pure friction bolting mechanism allows to overcome large displacements without failing, the bolt capacity is typically half of the tensile strength of the steel tube.

Main applications of friction stabilizer type bolts are:

- Systematic reinforcement in underground excavations
- Generally temporary ground control purposes
- Bolting in medium to hard ground
- Supplementary and utility bolting



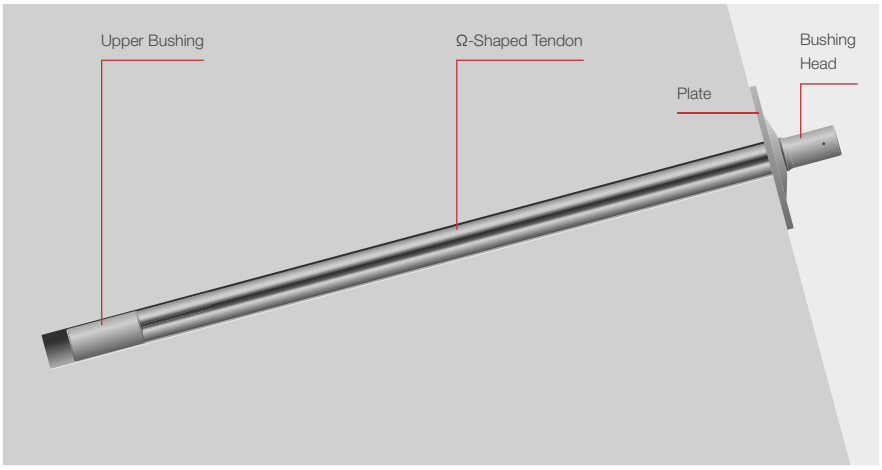
OMEGA-BOLT® (Water) Expandable Friction Bolts

The bolting mechanism of the OMEGA-BOLT® is based on friction and mechanical interlock. Bolt installation takes place in pre-drilled boreholes with a high-pressure water pump (supplementary Installation equipment), no bonding agent is required. Immediately after installation, the OMEGA-BOLT® is fully activated.

This system can be used in water-carrying boreholes and is fixed in vertical orientation by default. There is a limited use in soft ground conditions, bolt installation requires stable boreholes. The thin wall thickness of the bolt profile makes it sensitive to corrosion if not coated.

The OMEGA-BOLT® is used for:

- Systematic reinforcement in underground excavations
- Fast and flexible bolting operations
- Generally used for temporary ground control purposes

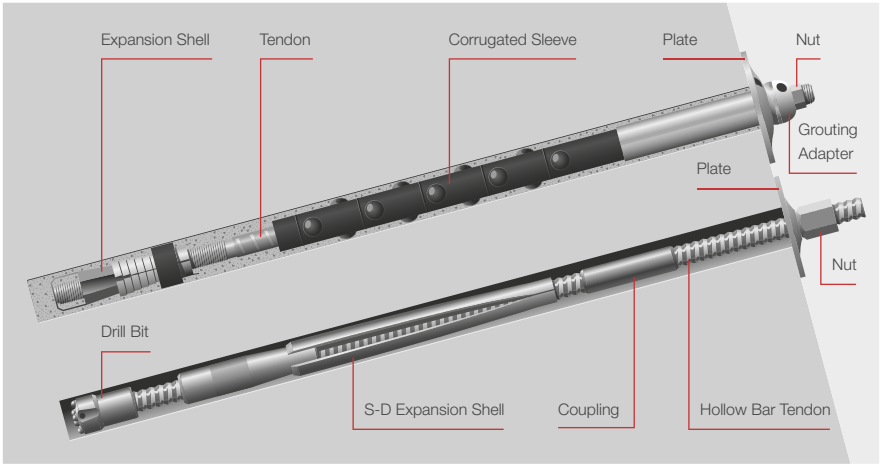


Combination Type Bolts

Combination bolts are a hybrid system providing both a mechanical anchorage and continuous bonding. They are perfectly suited for mechanized installation, immediate anchorage is provided after installation. Enhanced corrosion protection can be attained by the introduction of plastic sleeves between tendon and bonding agent. Both conventional and self-drilling versions are available.

Combination bolts are typically used for:

- Systematic permanent reinforcement of underground structures with an extended lifetime
- Ground support of areas with limited or no access during operational lifetime
- Hydroelectric power plants and underground oil or gas storage caverns
- Sub-sea and sewer tunnels



Corrosion Protection

DSI Underground offers a wide range of corrosion protection systems for bolts. Selection of the proper corrosion protection system is accomplished depending on the intended lifetime of the bolt and given corrosive environment. The most common protection methods for bolts are:

- Electrolytic galvanizing
  - Bonding of zinc to steel by an electro-chemical reaction
- Hot-dip galvanizing
  - Coating of a steel part with a layer of zinc by immersing the metal in a bath of molten zinc
- Sherardizing
  - Vapor galvanization
- Epoxy painting
  - Coating by application of a paint
- Duplex coatings
  - Combination method of hot-dip galvanization and powder coating

Furthermore, the sacrificial corrosion principle (see catalogue section “DSI Hollow Bar System”) is commonly used in civil engineering and for underground applications.

Introduction

By definition, corrosion is the reaction of a material with its ambient environment, causing a measurable change in the material (e.g. rust) which can lead to function impairment of a component or system. From a practical point of view, a complete corrosion protection cannot be achieved.

Therefore, applied protective methods are directed towards a reduction of the corrosion attack and the respective damages to the reinforcement or ground control elements during their intended service life.

Corrosion refers to the entire system, e.g. reinforcement element, grout body, ground, and corrosion media. It is expressed in terms of two main mechanisms of action: “corrosion of concrete” and “corrosion of the reinforcement in the concrete”.

Corrosion Protection Methods

The selection of the optimum corrosion protection method(s) depends on the corrosion potential of the environment, as well as type and intended service life of the structure.

The load-bearing element, transition zone between borehole and surface, and the head construction must be assessed separately.

Corrosion protection methods are divided into two main groups.

The first one is called active corrosion protection, and comprises all influencing methods which eliminate or reduce the corrosion reaction. A common example for active corrosion protection is encapsulation with concrete.
The second one is passive corrosion protection, including methods to produce a protective layer on corrosion endangered parts, for example duplex coating systems.

A preferred and recommend active corrosion protection method is the sacrificial corrosion design principle, which is based on corrosion rates of blank and galvanized steel depending on the corrosive environment and the expected lifetime, without considering cement stone encapsulation. Double corrosion protection (e.g. factory-made grouted corrugated sheathing) is not used for self-drilling applications.
Duplex type coatings can be damaged by the self-drilling installation process.

Sacrificial Corrosion Protection

- Definition of corrosion rates (sacrificial corrosion), depending on ground conditions and other influencing factors
- Element design in accordance with an increase of cross-section due to corrosion over the intended service life
- The system inherent encapsulation with cement mortar or grout is not considered
- Blank or galvanized ground control elements – galvanization leads to a delay of the corrosion start and to an increased service life
- Hot-dip galvanizing: preferred method for load-bearing system components in accordance with ISO 1461 or national standards
- Corrosion protection of head constructions must be assessed separately

Working Life According to European Standards and Approvals

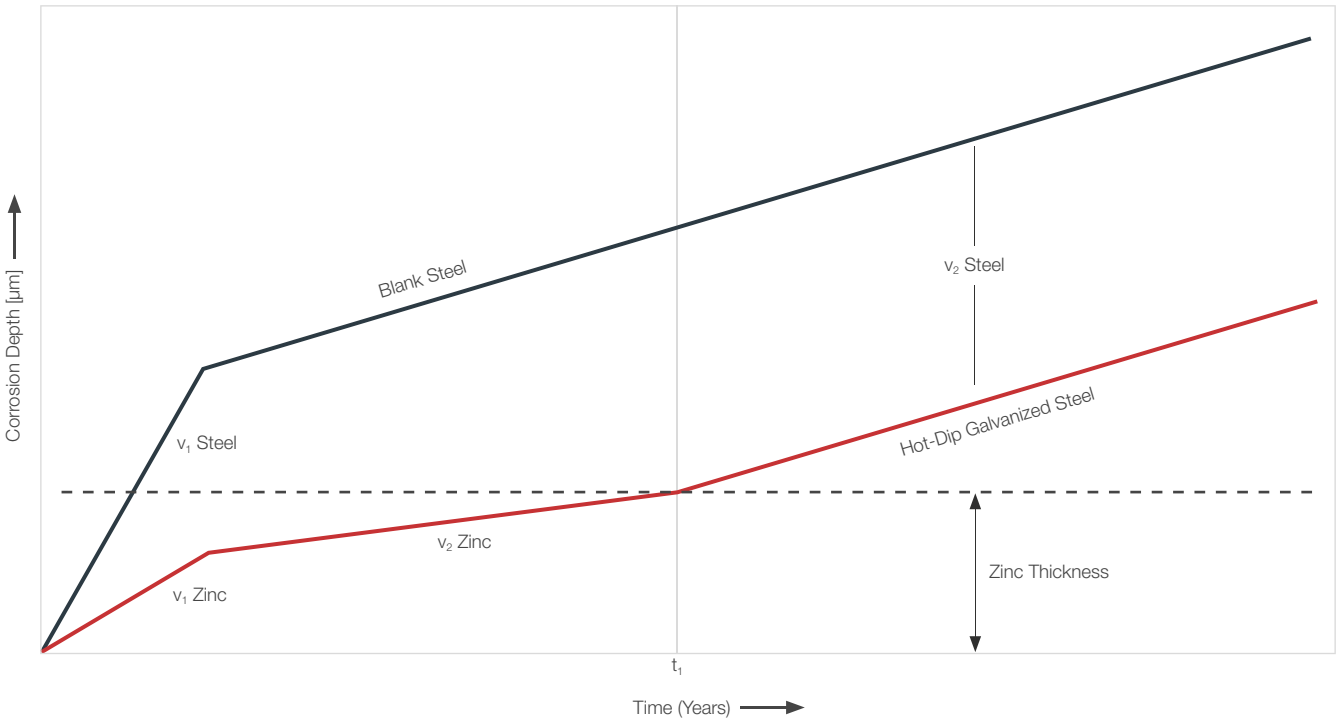
Working Life [1]	Steel [2]	Corrosion in [mm] for Different Corrosion Loads [3]		
Years	[–]	Low	Medium	High
2	Blank	0	0	0,2
	Hot-dip galvanized	0	0	0,1
7	Blank	0,2	0,2	0,5
	Hot-dip galvanized	0	0,1	0,4
30	Blank	0,3	0,6	–
	Hot-dip galvanized	0,1	0,4	–
50	Blank	0,5	1,0	–
	Hot-dip galvanized	0,3	0,7	–

1) A working life up to 100 years can be considered in accordance with EN 1993-5.

2) Typically applied average zinc layer thickness: ≥ 85 [µm] in accordance with ISO 1461.

3) According to ETA-21/0869. EN 14490 and EN 14199 also define classes of ground aggressiveness and corrosion rates for achieving the intended working life. Low, medium, and high corrosion loads are defined in EN 12501-2.

Corrosion Behavior of Blank and Hot-Hip Galvanized Steel in Soil (ETA-21/0869) [1]



1) Prof. Dr.-Ing. Habil. Prof. H.C. Ulf Nuernberger, expertise “Korrosionstechnische Beurteilung des DSI Hohlstab-Systems fuer Bodennnaegel, Pfaehle und Erdanker”.

DSI Hollow Bar System

Introduction

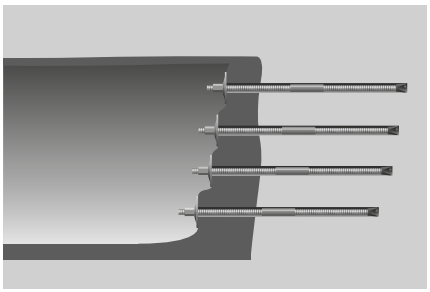
The DSI Hollow Bar System is a self-drilling ground control solution used for underground applications and in civil engineering. Underground, it can be used for bolting, foot piles, face stabilization, as forepoling element for pre-support, or as a lance for injection works.

The DSI Hollow Bar System also features a wide range of applications in civil engineering such as rock and soil nails, micropiles, or ground anchors.
The system is an “all in one” tool for drilling, flushing, post- or simultaneous grouting, and finally the load-carrying member itself.

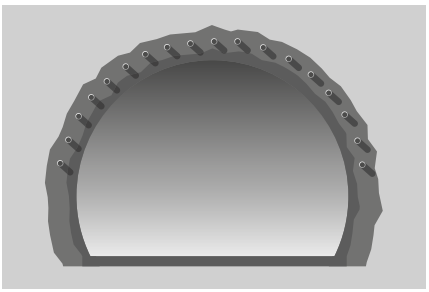
Installations in weak ground and unstable borehole conditions represent no difficulty and are ideal for the application of the DSI Hollow Bar System.
DSI Underground has long-term experience in the design, development, manufacturing, testing, and distribution of the DSI Hollow Bar System.

Fields of Application

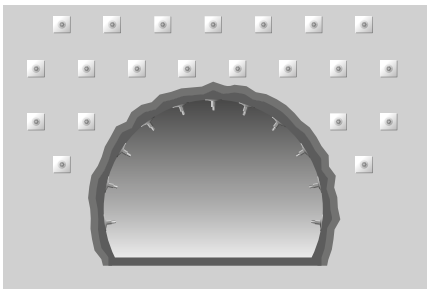
Face Bolting



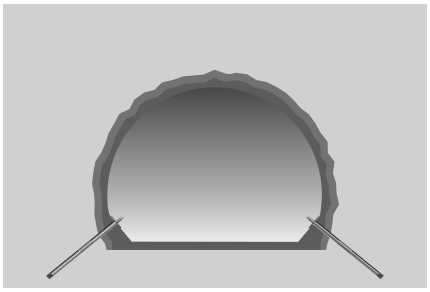
Injection Works



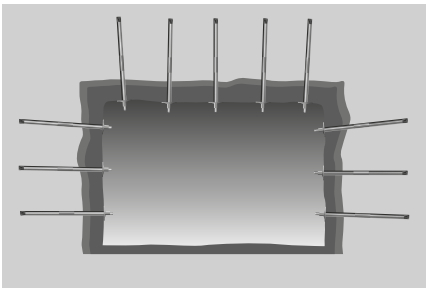
Portal Stabilization



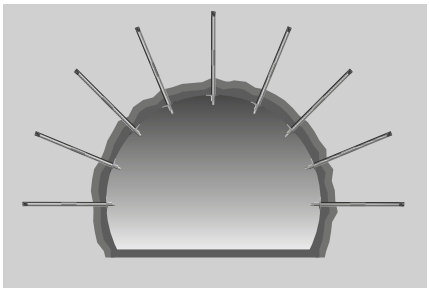
Footwall Stabilization



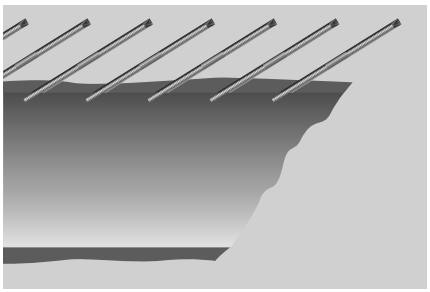
Roof and Rib Bolting



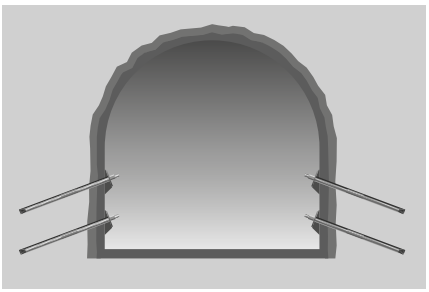
Radial Bolting



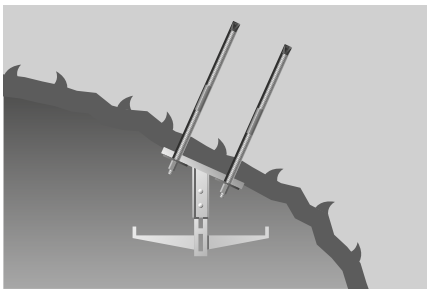
Forepoling



Prestressed Anchors



Utility Hangers



System Description

- Self-drilling ground control solution
- Preferably used under unstable borehole conditions
- Self-drilling installation without casing using a lost drill bit
- Installation with standard rotary or rotary-percussive drilling machines
- Hollow bar with continuous left-hand, cold-rolled outside thread, utilized as drill rod during installation
- Easy extension of hollow bars using couplings
- Grouting can either be performed during drilling with a rotary injection adapter or after the drilling operation
- Threaded profile allows an ideal bond between the hollow bar and the grouting medium

Main Advantages

- Fast and safe self-drilling installation
- Trouble-free application in unstable boreholes
- Easy and similar operating principle using on-site personnel and standard drilling machinery
- Drilling, installation, and optional grouting in a single operational step
- Proven installation process in difficult ground conditions
- Sound and efficient alternative compared to time-consuming cased drilling installation methods and products
- Same installation principle for all applications and ground conditions
- Minimization of ground disturbance
- Drill bit designs and diameters can be adjusted to different and varying ground conditions
- Minor space requirements for installation
- Functional adjustment of required lengths using couplings
- Broad range of hollow bar load capacity classes allows basic dimensioning and adaptation of design
- Robust system and high-strength thread designed for the demands of the construction industry
- High level of quality control measures among all levels of design and manufacturing

System Components

Basic Elements

- Hollow bar
  - Used as drill rod during installation
  - Suitable for simultaneous or subsequent grouting
  - Tension or compression member
- Coupling
  - Continuous inside thread with middle stop or center bridge
  - Controlled drilling energy transmission
  - Full load-bearing capacity
- Drill bit
  - One drill bit per installed unit
  - Different diameters and designs
  - Hardened and carbide insert versions
  - Optimized for various ground conditions

Anchorage and Foundation Constructions

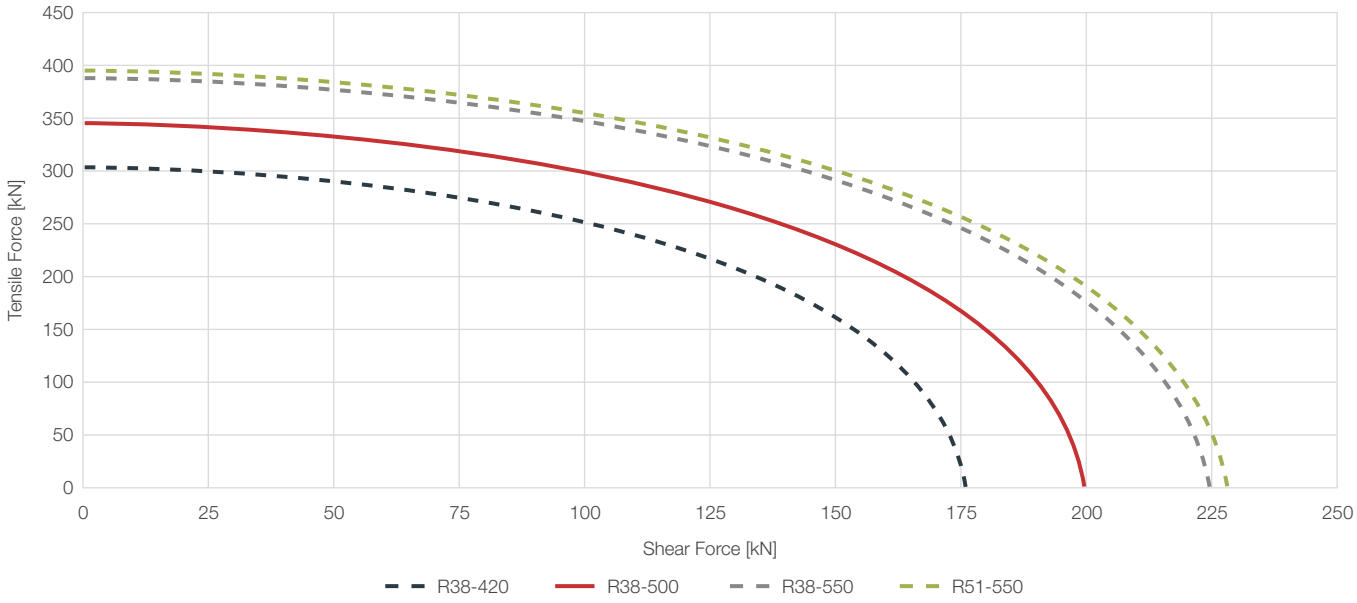
- Nut
  - Hex or domed version
  - Weldable square nut
  - Different designs and dimensions available
- Plate
  - Flat or domed
  - Plate design adjusted to system demands
  - Various solutions for angle compensations and special plate designs available

Nail Head with Domed Plate

Anchor Head with Angle Compensation

Rock and Soil Nails

Relationship of Tensile and Shear Force

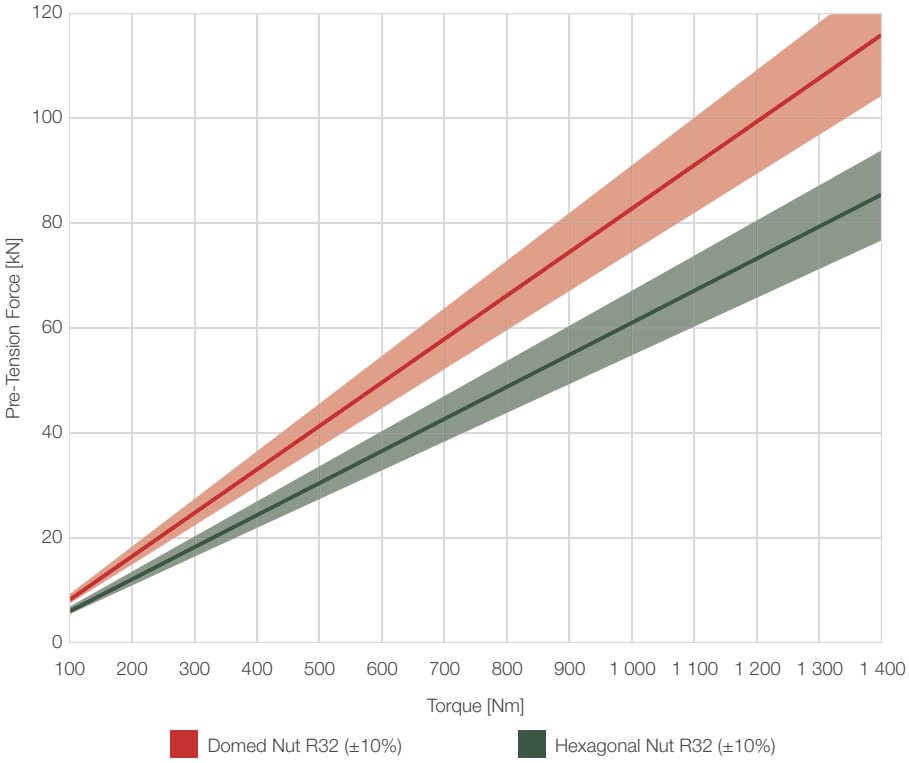


- Design value tensile stress $\sigma_{R,d} = \frac{f_{y,k}}{1,15}$
- Design value shear stress $\tau_{R,d} = \frac{f_{y,k}}{\sqrt{3} \cdot 1,15}$
- Ultimate shear load (design) $Q_v = \sqrt{(\sigma^2_{R,d} + 3 \cdot \tau^2_{R,d})}$

Approvals

- European Technical Assessment (ETA)
- National technical approval in Austria (BMK)
- National technical approval in Slovenia (STS)
- German Mining Approval
- National technical approval in Slovenia (ZAG)
- Project-specific approvals

Torque-Tension Diagram Type R32-280



Domed Nut R32

Hexagonal Nut R32

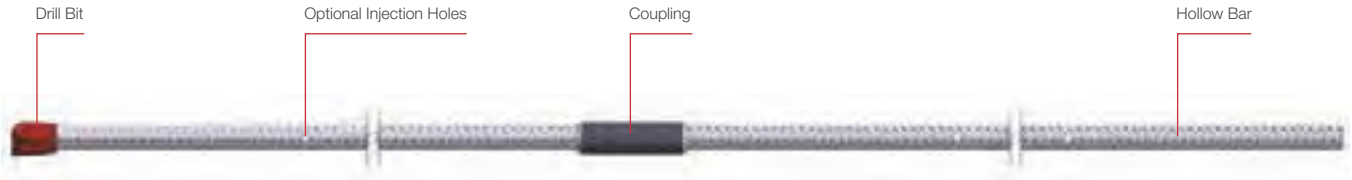
Injection Lances and Spiles

Basic Concept

Spiles are used as temporary pre-support elements for the stabilization of the working area in tunnel headings. They are installed in the crown and sidewall area of a tunnel, to ensure the stability of the perimeter of the open span until the primary lining is installed. Injection lances are used for the targeted transport of a cement or resin based injection medium to the designated injection area.

In difficult ground and in case of unstable boreholes, hollow bar spiles and injection lances are a preferred solution to ensure a safe and fast installation procedure. Self-drilling spiles and injection lances allow the use of default underground drilling machinery (jumbos); threaded hollow bars enable a durable and easy connection to any injection hose system.

A detailed description of spiles and injection lances is included in the catalogue sections “Pre-Support and Drainage” and “Injection Chemicals”.



Specifications

SI Units

Technical Data Series R32

Characteristic Value / Type [1]	Symbol	Unit	R32-250	R32-280	R32-320	R32-360	R32-400
Nominal external diameter	$D_{e,nom}$	[mm]			32		
Actual external diameter	D_e	[mm]			31,1		
Average internal diameter [2]	D_i	[mm]	20,0	18,5	16,5	15,0	12,5
Nominal cross-sectional area [3]	S_0	[mm²]	370	410	470	510	560
Nominal weight [4]	m	[kg/m]	2,90	3,20	3,70	4,00	4,40
Nominal yield load [5]	$F_{p0,2,nom}$	[kN]	190	220	250	280	330
Nominal ultimate load [5]	$F_{m,nom}$	[kN]	250	280	320	360	400
Ultimate load strain [7]	A_{gt}	[%]			≥ 5,0		

Technical Data Series R38 and 51

Characteristic Value / Type [1]	Symbol	Unit	R38-420	R38-500	R38-550	R51-550	R51-660	R51-800	R51-925
Nominal external diameter	$D_{e.nom}$	[mm]		38			51		
Actual external diameter	D_e	[mm]		37,8			49,8		
Average internal diameter [2]	D_i	[mm]	21,5	19,0	17,0	34,5	33,0	29,0	29,5
Nominal cross-sectional area [3]	S_0	[mm²]	660	750	800	890	970	1,150	1,275
Nominal weight [4]	m	[kg/m]	5,15	5,85	6,25	6,95	7,65	9,00	10,00
Nominal yield load [5]	$F_{p0.2,nom}$	[kN]	350	400	450	450	540	640	740
Nominal ultimate load [5]	$F_{m,nom}$	[kN]	420	500	550	550	660	800	925
Ultimate load strain [7]	A_{gt}	[%]				≥ 5,0			

1) All values are subject to change. The decimal marker symbol is a comma character (","), while thousands separators are blank spaces – this applies for all numbering in this catalogue. Other hollow bar types with similar load capacity classes, alternative steel grades, and deviating characteristic values (D, S, m) are available upon request. The DSI Hollow Bar System made in Austria is CE marked, the Self-Drilling Hollow Bar System is provided without approval. Larger diameter hollow bars (T76 and above) are available as well.

2) Calculated from the actual external diameter, the average thread height, and the nominal cross-sectional area, rounded.

3) Calculated from the nominal weight $S_0 = 10^6 \times m / 7\,850$ [kg/m³].

4) Deviation: -3% to +9%.

5) Characteristic value (5%-fractile).

6) Calculated from the nominal load and the nominal cross-sectional area, rounded.

7) Characteristic value (10%-fractile).

Modulus of elasticity E = 205 000 [N/mm²].

US Customary Units

Technical Data Series R32

Characteristic Value / Type [1]	Symbol	Unit	R32-250	R32-280	R32-320	R32-360	R32-400
Nominal external diameter	$D_{e,nom}$	[in]			1,26		
Actual external diameter	D_e	[in]			1,22		
Average internal diameter [2]	D_i	[in]	0,79	0,73	0,65	0,59	0,49
Nominal cross-sectional area [3]	S_0	[in²]	0,57	0,64	0,73	0,79	0,87
Nominal weight [4]	m	[lb/ft]	1,95	2,15	2,49	2,69	2,96
Nominal yield load [5]	$F_{p0.2,nom}$	[kip]	43	49	56	63	74
Nominal ultimate load [5]	$F_{m,nom}$	[kip]	56	63	72	81	90
Ultimate load strain [7]	A_{gt}	[%]			≥ 5,0		

Technical Data Series R38 and 51

Characteristic Value / Type [1]	Symbol	Unit	R38-420	R38-500	R38-550	R51-550	R51-660	R51-800	R51-925
Nominal external diameter	$D_{e,nom}$	[in]		1,50			2,01		
Actual external diameter	D_e	[in]		1,49			1,96		
Average internal diameter [2]	D_i	[in]	0,85	0,75	0,67	1,36	1,30	1,14	1,16
Nominal cross-sectional area [3]	S_0	[in²]	1,02	1,16	1,24	1,38	1,50	1,78	1,98
Nominal weight [4]	m	[lb/ft]	3,46	3,93	4,20	4,67	5,14	6,05	6,72
Nominal yield load [5]	$F_{p0.2,nom}$	[kip]	79	90	101	101	121	144	166
Nominal ultimate load [5]	$F_{m,nom}$	[kip]	94	112	124	124	148	180	208
Ultimate load strain [7]	A_{gt}	[%]				≥ 5,0			

1) All values are subject to change. The decimal marker symbol is a comma character (","), while thousands separators are blank spaces - this applies for all numbering in this catalogue. Other hollow bar types with similar load capacity classes, alternative steel grades, and deviating characteristic values (D, S, m) are available upon request. The DSI Hollow Bar System made in Austria is CE marked, the Self-Drilling Hollow Bar System is provided without approval. Larger diameter hollow bars (T76 and above) are available as well.

2) Calculated from the actual external diameter, the average thread height, and the nominal cross-sectional area, rounded.

3) Calculated from the nominal weight.

4) Deviation: -3% to +9%.

5) Characteristic value (5%-fractile).

6) Calculated from the nominal load and the nominal cross-sectional area, rounded.

7) Characteristic value (10%-fractile).

Modulus of elasticity E = 29 700 [ksi].

Drill Bits

Introduction

The drilling performance is affected by the choice of the proper drill bit, which mainly depends on the hardness and abrasiveness of the ground, the drilling method, borehole diameter, and borehole length.

Furthermore, the drill bit and therefore the borehole diameter depend on the application (e.g. rock or soil nails, micropiles, etc.).

A key issue during the self-drilling installation procedure is to minimize the impact on the surrounding soil or rock by optimizing drilling rates and the applied energy.

For example in mixed fill type soils, drill bit types typically used are two-stage retro flush drill bits, arc-shaped drill bits, or cross drill bits.

Ground such as clays, loams, soft slate, or clayey silt is removed in terms of cutting and scraping. For these soil types, two-stage flush drill bits, arc-shaped drill bits, and cross drill bits are typically used.

In harder soil or rock, the use of percussive energy plays a more dominant role. In this case, button drill bits, cross drill bits, or arc-shaped drill bits are typically used in combination with carbide inserts.

Ground Properties			Drill Bit Type [1]								
Designation	Description	Examples	Two-Stage R-Flush and RS-Flush	Arc-Shaped Button, Hardened	Arc-Shaped Button, Carbide Inserts	Arc-Shaped, Hardened	Arc-Shaped, Carbide Inserts	Cross, Hardened	Cross, Carbide Inserts	Button, Hardened	Button, Carbide Inserts
											
Alluvium	– Humus and organic layers – Peat and sludge – Gravel, sand, silt and clay mixtures	– Top soil or flowing ground, possibly water-bearing – Sedimentary fills, fault zone material	X	(X)		(X)		X			
Sands	– Non-cohesive and cohesive sand, gravel, and mixtures with small clay contents	– Easily removable soil – Mixed fills	X	(X)	(X)	X		X			
Cohesive soils	– Mixtures of sand, gravel, silt, and clay	– Average removable soil – Mixed fills	(X)	X	X	X	(X)	X	(X)		
Gravel	– Soils with a higher gravel content of larger sizes	– Difficult removable soil – Riverbeds		(X)	X	(X)	X	(X)	X		
Soft rock	– Jointed, brittle, weathered – Conglomerate	– Average removable rock – Limestone, schist			X	(X)	X		X	X	X
Hard rock	– Higher abrasiveness and/or compressive strength, less fractured	– Difficult removable rock – Volcanic rock, hard sandstone, concrete					(X)		(X)	(X)	X

1) Indications are general guidelines and depend on on-site conditions. Borehole diameter and drilling length influence drill bit selection.
"X" markings show standard applications, "(X)" markings possible combinations.

Portfolio

- Successful installation performance depends on selecting the adequate drill bit
- Large drill bit portfolio for various ground conditions
- Selection of optionally used centralizers must be accomplished dependent on the drill bit diameter
- Optimized in regards to installation parameters such as cutting ability and drilling performance
- Adjusted to the requirements of civil engineering as well as for underground applications
- Further information regarding drill bit design and selection are included in a separate leaflet on drill bits for the DSI Hollow Bar System

Diameter [1]		Thread	Drill Bit Type [1]									
[mm]	[in]	Type	Two-Stage R-Flush (Retro-Flush), Hardened	Two-Stage RS-Flush (Retro & Side Flush), Hardened	Arc-Shaped Button, Hardened	Arc-Shaped Button, Carbide Inserts	Arc-Shaped, Hardened	Arc-Shaped, Carbide Inserts	Cross, Hardened	Cross, Carbide Inserts	Button, Hardened	Button, Carbide Inserts
												
51	2,0	R32					X	X	X	X	X	X
		R38										
		R51										
		T76										
76	3,0	R32		X	X	X	X	X	X	X	X	X
		R38			X	X	X		X	X	X	X
		R51			X	X					X	X
		T76										
90	3,5	R32			X	X						
		R38			X	X			X	X	X	X
		R51			X	X						
		T76										
100	3,9	R32		X								
		R38		X							X	X
		R51							X	X	X	X
		T76										
115	4,5	R32										
		R38			X	X			X	X	X	X
		R51			X	X			X	X	X	X
		T76										
130	5,1	R32										
		R38		X								
		R51			X						X	
		T76			X	X			X	X	X	X
150	5,9	R32										
		R38										
		R51		X								
		T76	X		X	X			X		X	X
200	7,9	R32										
		R38										
		R51										
		T76	X						X			

1) X-marked fields indicate standard drill bit types, other dimensions available upon request.

Self-Drilling Installation

Self-drilling installation may be accomplished either semi-mechanized or fully mechanized, depending on the available drilling machinery.

The DSI Hollow Bar System offers high rates of installation, as drilling and grouting can be combined into one single operational procedure.

Selection of the proper drilling machinery is key to ensure efficient and sound drilling.

Installation Parameters

Self-drilling installation is accomplished using either rotary or rotary-percussive drilling machines. Depending on the application, the ground conditions, the hollow bar type, as well as the final installation length. The main drilling parameters which are listed and described in the following have to be adjusted accordingly.

Rotation Speed

The rotation speed is controlled by the rotation motor used. While underground rotation motors of (hydraulic) rock drills run on higher rotation rates and the final installed element length is normally short, experience from civil engineering applications has shown that rates in the range of 120 to 150 [rpm] provide sound results.

Torque

The recommended maximum torque for the installation of the DSI Hollow Bar System has been determined for different types and feed ratios. These values have been determined numerically with a safety factor of 0,7 with regards to the yield load.

Percussion

Different types of rock drilling equipment feature a wide range of percussion rates. In general, the same percussion rate as for default “smooth rock/soil drilling” using drill steel and multiple-use drill bits should be applied. For directional stability and drilling efficiency in civil engineering, percussion rates of 300 to 600 [bpm] have shown good results.

Feed

The recommended maximum feed range for installation depending on the hollow bar type and the applied torque is shown in the following diagram.

For shorter installation lengths required for underground applications, adjustment of the feed rate is not as critical as in civil engineering, where the stability and accuracy of the drill string are key features. Here, the feed pressure should be adjusted so that it matches the achievable smooth drilling rate.

Grouting

Grout mixing pumps used for injection of the DSI Hollow Bar System typically comprise of a mixing and a pumping unit. Those injection pumps must feature a complete mixing of the grout and a steady pumping pressure.
For simultaneous drilling and grouting, pressure requirements are not high (< 7 [bar] / 100 [psi]), hence a constant supply rate is required to ensure that the grout circulates within the borehole during drilling. The grouting pressure must be customized to respective and machine capacity.
For example, the required pressure is higher for long ground anchors than for short bolts.

The consumption of injection medium mainly depends on:

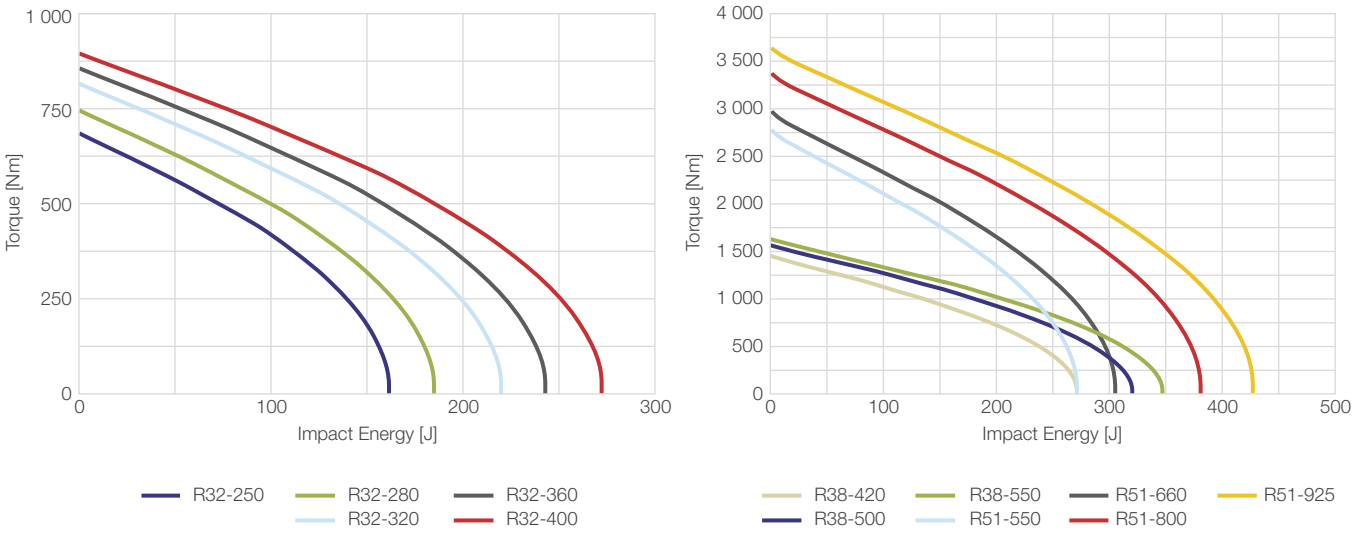
- Amount and type of flushing medium
  - Air, water, water-air mixture, or grout
  - Simultaneous drilling and grouting is a combined flushing and injection technique
- Ground conditions
  - Non-binding soils or fractured rock result in an increased consumption of injection media
- Water-cement ratio
  - Generally between 0,35 and 0,70

Besides the common self-drilling installation feature, grouting may either be performed while drilling with a rotary injection adapter or after the drilling operation. This subsequent grouting procedure is accomplished with a conical push adapter or a threaded coupling connector. In case given ground conditions require further improvement, multiple injections using post-injection couplings further enhance the grouting performance. Additional injection holes drilled into hollow bars may also support grout distribution along the entire element length; however, they reduce the load-bearing capacity of the hollow bar tendon.

Simultaneous Drilling and Grouting

This technique ensures that the grout is properly and uniformly distributed over the entire installation length as drilling advances, and has shown proper results in ground types where a cement grout bulb around the hollow bar cannot be properly established by post injection grouting. Grout which replaces water or air as a flushing medium is injected into the drill string over a rotary injection adapter; it permeates the ground concurrently with the installation and forms bulbs for increased bond strength. For granular soils, a small return of grout at the collar of the borehole is required. For cohesive soils, larger grouting/ flushing amounts may be necessary.

Recommended Pairs of Impact Energy and Torque



Installation Methods

Simultaneous Drilling and Grouting

– Assembly of the DSI Hollow Bar System and connection to the rotary injection adapter

– Rotary self-drilling installation and simultaneous grouting

– Optional extension using couplings

– De-coupling from the rotary injection adapter

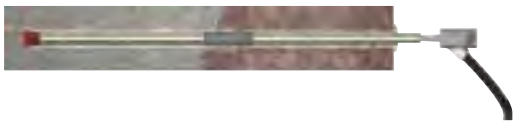
Drilling and Subsequent Grouting

– Assembly of the DSI Hollow Bar System and connection to the rotary drill

– Rotary percussive self-drilling installation without casing: single-use drill bit and hollow bar drill steel, water or air-water mixture flushing

– Optional extension using couplings

– De-coupling from the drilling machinery; subsequent grouting using an injection adapter



– Assembly of anchorage or head construction (plate and nut), depending on the application

S-D Expansion Bolt

Introduction

In the past decade, various so-called "one-step" bolting systems have been developed. This is a result of steadily increasing requirements on installation procedures and the ensuing higher needs for self-drilling bolts. The self-drilling bolt product family has now been extended by an expansion shell element for the DSI Hollow Bar System.

This innovative S-D (self-drilling) expansion bolt is used both for underground applications and in civil engineering. The key factor for the success of this combination bolt type is the use of the long-term proven DSI Hollow Bar System principle with a robust and innovative expansion element.

The S-D expansion bolt is installed self-drilling; borehole drilling and bolt installation are accomplished in one operational step. The system's adaptability to changing ground conditions is an important feature. Immediately after the self-drilling installation, an activation of the expansion element leads to an instant load-bearing capacity.

The S-D expansion bolt can be optionally tensioned following the fixation of plate and nut.

Subsequent grouting, de-coupled from the actual installation procedure, permits further optimization of installation cycle times.

One important application in civil engineering is the use in excavation pits, where the construction process requires an immediate load-bearing capacity. Underground, face support (face bolts) and longer vertical bolts (large-span support in caverns) are typical application examples for this type of self-drilling combination bolt.

System Description

- Expansion bolt: mechanically anchored and fully grouted
- Self-drilling installation based on the principle of the DSI Hollow Bar System
- Hollow bar with continuous cold-rolled left-hand outside thread utilized as drill rod during installation
- Rotary-percussive installation using standard underground drilling machines
- Conventional or mechanized installation
- Immediate load-bearing capacity via the mechanical end anchorage
- Subsequent optional grouting feature
- Flexible application range from 210 to 800 [kN] (47 - 180 [kip]): R32-210 to R51-800
- Utilization of several subsequently aligned extension expansion elements allows a higher load-bearing capacity even in weak ground

System Components

- Drill bit
  - Single-use drill bits in different diameters and designs
  - Hardened or carbide inserts
- S-D expansion element
  - Standard diameters: R32, R38, and R51
  - R38 and R51: several coupled extension expansion elements can be used
- Hollow bar tendon R32, R38, or R51
- Plate
  - Different designs and dimensions available upon request
- Nut
- Drive adapter
  - Couplings in different versions

S-D Expansion Bolt Type R38-076 with two Coupled Expansion Elements

Main Advantages

- Immediate load-bearing capacity after installation and activation of the expansion element
- Cycle time reduction due to the de-coupling of the grouting procedure from installation
- Ability to maintain load-bearing capacity even when undergoing large deformations
- Tough system components
- Safe, easy, and reproducible installation procedure
- Improved drilling accuracy thanks to the directional guidance of the self-drilling expansion element

Ready-For-Use S-D Expansion Bolt R32-051

Installation Procedure

- Assembly and connection of the drive adapter to the rock drill
- Rotary percussive self-drilling installation (counterclockwise rotation) without casing: single-use drill bit and hollow bar drill steel, water or air-water mixture flushing
- Optional extension using couplings
- Activation of the expansion element after the final drilling depth has been reached: withdrawal of the rock drill with hammer strokes
- De-coupling of the drive adapter
- Fixation and assembly of the anchorage (plate and nut)
- Optional de-coupled grouting

Expansion Shell

Introduction

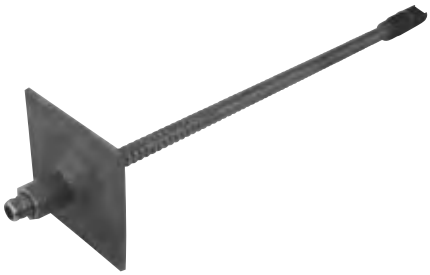
Bolts with a variable free length ensure a pre-tensioning of the anchor and thus an active force transmission.

The hollow bar expansion shell anchor is installed into pre-drilled boreholes. Immediate load-bearing capacity is achieved by an activation of the expansion shell.

The injection of the annular gap between the hollow bar tension member and the borehole using cement grout or DSI Inject Systems is accomplished in a second working step.

Main Advantages

- Simple handling and optimized installation time
- Immediate loading-bearing capacity
- Unproblematic installation in aquiferous boreholes
- The choice of the appropriate hollow bar ensures the optimal anchor force
- Continuous hollow bar thread allows flexible length adjustments and posterior extension on-site
- Available for series R32, R38, and R51



Specifications

Characteristic Value / Type	Symbol	Unit	SK-R32-048	SK-R38-068	SK-R51-078
Nominal external diameter	$D_{e,nom}$	[mm]	48	68	78
		[in]	1,9	2,7	3,1
Length	L	[mm]	170	186	230
		[in]	6,7	7,3	9,1
Nominal weight	m	[kg]	1,8	4,0	7,8
		[lb]	4,0	8,8	17,2
Required borehole diameter	Db	[mm]	52 - 58	72 - 78	90 - 95
		[in]	2,0 - 2,3	2,8 - 3,1	3,5 - 3,7
Nominal load-bearing capacity [1]	$F_{m,nom}$	[kN]	230	400	630
		[kip]	52	90	142

1) Determined in the course of laboratory pull tests in model rock mass (concrete).

Installation Procedure

- Drilling of a borehole in accordance with the specifications, approx. 150 [mm] (6 [in]) longer than the expansion shell anchor when installed
- Insertion of the assembled expansion shell anchor into the borehole – shell must fit into the borehole tightly
- Pre-tensioning via impact screw driver or adequate driver tool
- Optional post grouting after installation

Yielding Anchor Head

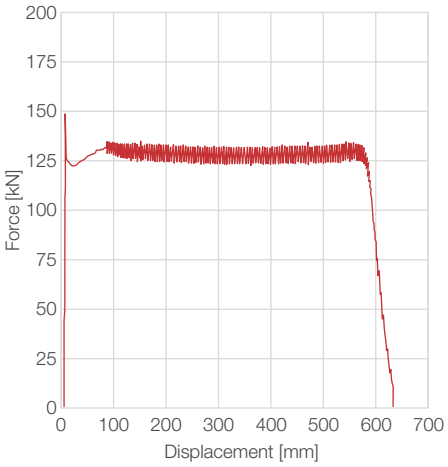
Introduction

The yielding anchor head plus integrated free (de-bonded) length is used for applications in squeezing and loose ground. Installation is accomplished either self-drilling or in a pre-drilled borehole; the bond length is grouted.

Main Advantages

- Controlled accommodation of large deformations
- Adjustable to given ground conditions
- Constant high yielding force level
- Tough and durable design
- German approval for underground application
- Simple and secure manipulation of pre-assembled components

Yielding Characteristics



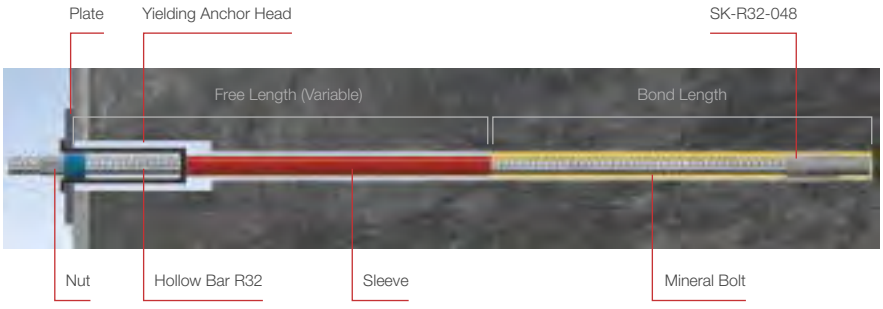
Specifications

Characteristic Value / Type	Unit	R32-GK 150-L [1]
Yield force	[kN]	130 - 150
	[kip]	29 - 34
Yield length	[mm]	Up to 600
	[in]	Up to 23,6

1) Recommended default hollow bar type: R32-360.

Basic Concept

Installation Principle



Working Mechanism

- Load transfer
  - Bond length: grouted, preferably in combination with an expansion shell
  - Anchorage: plate and yielding anchor head
- Working mechanism
  - Ground deformations result in an elongation of the hollow bar in the free length
  - Induced controlled yielding of the head construction
- Yielding anchor head
  - Discrete component
  - Absorbing mechanism based on a cylinder with integrated piston
  - Defined force-displacement characteristics
  - Adjustable to project-specific requirements

Post-Injection Coupling

Introduction

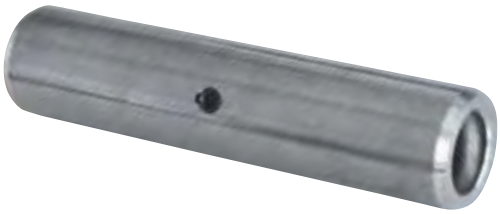
By default, the annular gap between hollow bar and ground is grouted via the outlet port at the drill bit to achieve improved load transmission.

The hollow bar post-injection coupling allows the targeted post-injection through the cleaned inner hole of the hollow bar using different injection media.

These injections can be carried out for ground improvement, sealing, or compensating grouting.

Main Advantages

- Application in all ground types
- No partial loss of drilling and cooling medium during installation
- Controlled and targeted post-injection of the ground
- Adjustable rated opening pressure



System Description

The standard coupling is replaced by a hollow bar post-injection coupling. This special coupling type allows targeted multiple injections through circumferentially aligned injection holes with valves. Valve opening pressures can be adapted upon customer request.

Specifications

- Available for series R32, R38, R51, and T76
- Designed for highest load-bearing capacities
  - R32-400
  - R38-550
  - R51-800 (R51-925)
  - T76-1900
- Factory-set adjustable rated valve opening pressure: from 8 to 20 [bar] (115 to 290 [psi])
- Integrated non-return function

Technical Features

- Handling during installation is the same as for standard couplings
- The load-bearing capacity of the system (hollow bar – coupling) remains completely intact
- Multiple injections can be accomplished through valves with injection holes

Installation Procedure

- Assembly of the DSI Hollow Bar System and connection to the rotary injection adapter
  - Note: self-drilling installation and subsequent grouting is also possible
- Rotary self-drilling installation and simultaneous grouting
  - Primary injection process through the drill bit
  - Extension of hollow bars with post-injection couplings
- Post-injection and final assembly
  - Flushing of the injection channel (inside of the hollow bar) with water using a plastic hose shortly after the installation is completed
  - Short curing time for the primary injection, depending on the grout mixture used (generally 12 to 18 hours)
  - Post-injection with an injection adapter through the hollow bar
  - Post-injection couplings with a pressure exceeding 8 [bar] (115 [psi])
  - Maximum injection pressure depending on application and ground conditions
  - Repetition of working steps if a consecutive injection process is required
  - Preparation of the head construction, if required

Utility Nuts, Anchorage Elements, and Drill Bit Adapters

Loop and Eye Nut

- Eye nut: heavy duty version
- Loop nut: standard version
- Utility hangers
- Fixation of ropes and mats
- Anchorage of mesh and geogrid

Angle Compensation Disks

- Secure anchorage even when undergoing large inclinations
- Standard application in combination with domed nuts
- Standard version for hollow bar series R32 and R38

Drill Bit Adapters

- Connection of hollow bar and drill bit threads of different diameters
- Large drill bit portfolio for diameter ranges outside standard versions
- Controlled transmission of the drilling energy from the hollow bar onto the drill bit

Injection Equipment

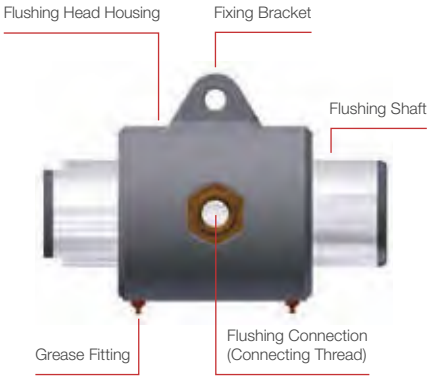
Rotary Injection Adapter

System Components

- Flushing head housing
- Flushing shaft with connecting thread for the hollow bar and the shank adapter
- Gasket and wiper (internal)
- Fixing bracket with connection thread for the injection hose
- Grease fitting
- Dampening rubber

Main Advantages

- Simultaneous drilling and grouting ensures an ideal bond with loose rock or soil
- Penetration of the injection material into the surrounding ground
- Ground improvement and homogeneous distribution of the injection material



Injection Adapter

- Different versions for cement grout or resin injection
- Conical push adapters or threaded adapter couplings
- Various grout hose connections available upon request

Continuous Bonded

Rebar Bolts (SN Bolts)

Main Advantages

- Field-proven bolting system
- Effective and standardized installation
- Embedding of the tension member in grout ensures optimal bond strength
- Low sensitivity concerning the actual diameter of the borehole
- ALWAGRIP special rib geometry for optimized bond strength available upon request

Standard Bolt Head with Plain Washer and Nut

System Components

- Bolt shaft (tendon)
  - Pointed or 45° cut, with cold-rolled thread at the far end, including nut and washer
  - Standard thread length approx. 120 [mm] (5 [in])
  - Special ALWAGRIP rib geometry for increased bond available
- Plate
  - Default bolt plate: domed, with long hole
  - Other bolt plates in different dimensions available upon request
- Washer and nut
  - Bolt head version with hemispherical washer available upon request
  - Optional free length using a sleeve

Specifications SI Units (EMEA)

Characteristics / Type [1]	Symbol	Unit	SN20-180	SN25-250	SN25-330	SN28-330	SN32-430
Nominal diameter	$D_{e.nom}$	[mm]	20	25	25	28	32
Thread	–	[mm]	M21	M26	M26	M30	M33
Nominal cross-section rebar [2]	S_0	[mm²]	315	491	491	616	804
Nominal weight rebar [3]	m	[kg/m]	2,47	3,85	3,85	4,83	6,31
Yield load rebar [4]	$F_{e.nom}$	[kN]	173	245	319	308	402
Ultimate load rebar [4]	$F_{m.s.nom}$	[kN]	190	260	340	330	462
Yield strength rebar [5]	$R_{e.nom}$	[N/mm²]	550	500	650	500	500
Tensile strength rebar [6]	$R_{m.s.nom}$	[N/mm²]	594	540	820	540	575
Ultimate elongation rebar [5]	A_{gt}	[%]			5,0		
Ultimate load bolt system [7]	$F_{m.A.nom}$	[kN]	180	250	330	330	430
Recommended wall thickness plate	s	[mm]	8	10	12	12	12
Wrench size nut	SW	[mm]	36	41	41	46	50
Delivery lengths [8]	L	[mm]	1 000 - 12 000				

1) Note: all values are subject to change; other types, dimensions, and steel grades are available upon request.

2) Calculated from the nominal weight: $S_0 = 10^6 \times m / 7\,850$ [kg/m³].

3) Characteristic fractile value.

4) Calculated from the characteristic load value and nominal weight, rounded.

5) Reinforcement steel B 500 B according to DIN 488-1 or OENORM B 4700; B 550 B according to OENORM B 4700; rock bolt steel FA 650/820.

6) Calculated from the ratio R_m/R_e or according to manufacturer specifications.

7) Nominal value ultimate system load: bolt head with cold-rolled thread, plate, washer, and nut.

8) Off-size lengths are available upon request.

Further information on alternative types of SN bolts can be found in local technical product brochures.

Installation Accessories

- Nuts
  - Plain
  - Domed
  - Flanged
  - With shear pin (drive nuts)
  - Forged head bolts upon request
- Washers
  - Round
  - Steel or plastic versions
  - Spherical seat: angle compensation
- Torque indicators and plates
  - See catalogue section “Bolt Accessories”
- Installation tools
  - For hand-held drifters and hydraulic rock drills
  - Hex or square nut drivers
  - Torque or impact wrench
  - Rebar pushers for different drilling machines
- Utility bolts
  - Eye nuts available upon request

Installation Procedure

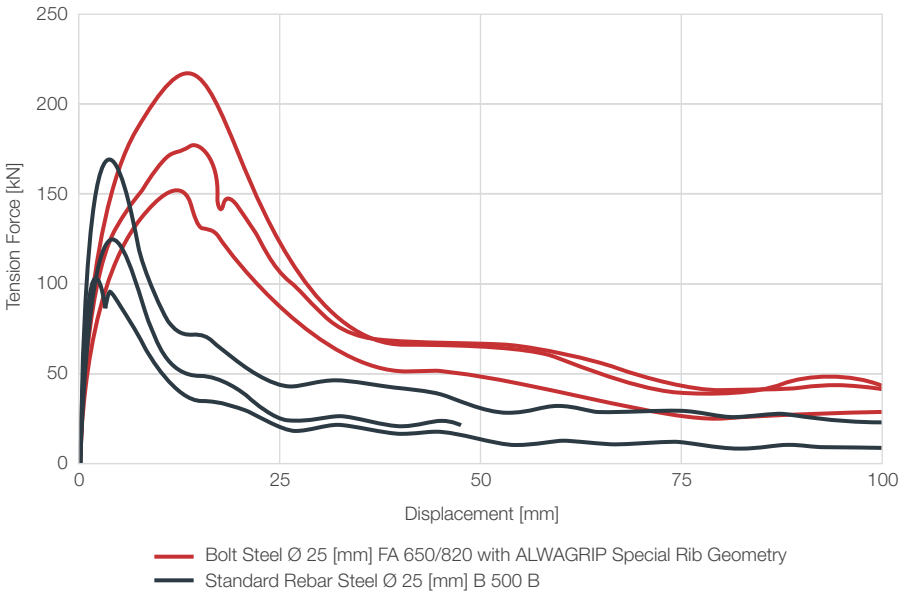
- Borehole drilling
- Filling of the boreholes with grout
- Manual insertion of SN-Bolts into the pre-filled boreholes, fixation in the borehole using a wedge or similar device
- Curing time is to be adjusted to the applied grout or valid installation instructions
- Tensioning of the bolt’s head by tightening of the nut

ALWAGRIP Special Rib Geometry

- According to the guideline RVS 8T, Austrian Research Association for Roads, Railways and Transport
- The rib geometry of conventional SN-Bolts is in accordance with the regulations of concrete steel reinforcement
- Obtained rib area between 0,02 and 0,04 (cf. RVS 8T)
- Ground deformations in Tunneling usually occur immediately after the installation of SN-Bolts, which is why the requirements for bond strength development differ from those of reinforced concrete construction
- Development of ALWAGRIP special rib geometry in accordance with the requirements for SN-Bolts in Tunneling, especially in squeezing ground conditions
- Material characteristics of SN-Bolts with ALWAGRIP special rib geometry are considerably better than for similar anchors and bolts with concrete reinforcement ribbing
- The advantages of using a steel grade with higher yield strength are observable after a curing time of 12 hours

Laboratory Pull Test Results

- Examination of the inner bond for two different bolt steel types depending on curing time
- Results of pull tests after 12 hours curing time, bond length 500 [mm] (20 [in])



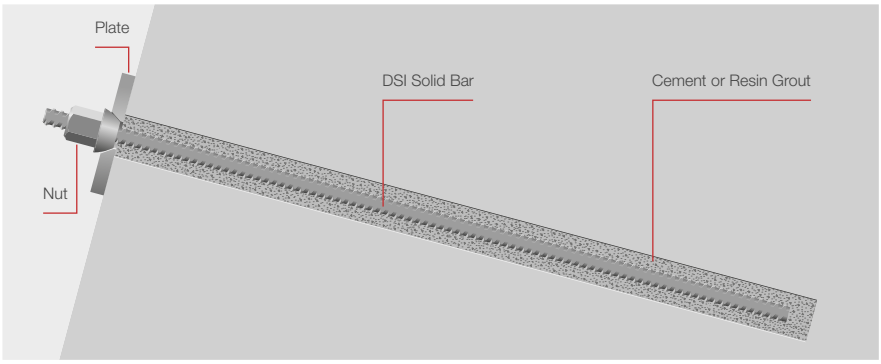
Further References

- Schubert, W. (Ed.): Recommendation – Fully mortared rock bolts (SN-Anchors) – Special Rib Geometry and requirements for the mortar; Institute of Rock Mechanics and Tunneling; Graz, Austria, 1997-07
- Bluemel, M.: Bearing load of rock bolts in squeezing rock mass, Proceedings ISRM International Symposium EUROCK '96 Turin, Italy, Balkema Rotterdam, 1996
- Bluemel, M.; Schweiger, H.F.; Golser, H.: Effect of Rib Geometry on the Mechanical Behaviour of Grouted Rock Bolts, Proc. of World Tunnel Congress '97, 23rd General Assembly of the International Tunnelling Ass., Vienna, Austria, 1997

DSI Solid Bar System

Main Advantages

- Optimized ratio of bolt capacity to borehole diameter
- Continuous threaded bar allows length adjustment and subsequent extension on-site
- Wear-resistant coarse thread according to the requirements in Tunneling



System Components

- DSI Solid Bar
  - With right or left hand coarse thread
  - Optional extension using couplings
- Plate
  - Domed or flat
- Nut
  - Domed or hexagonal
  - Eye bolts available upon request
- Double corrosion-protected version and free length systems with jacket tube available upon request
- Steel expansion shell available upon request
- DSI Mining Bolt type GS25-340
  - Special ductile steel 500/700 [N/mm²]
  - Increased ultimate elongation A_5: 20%
  - Available upon request

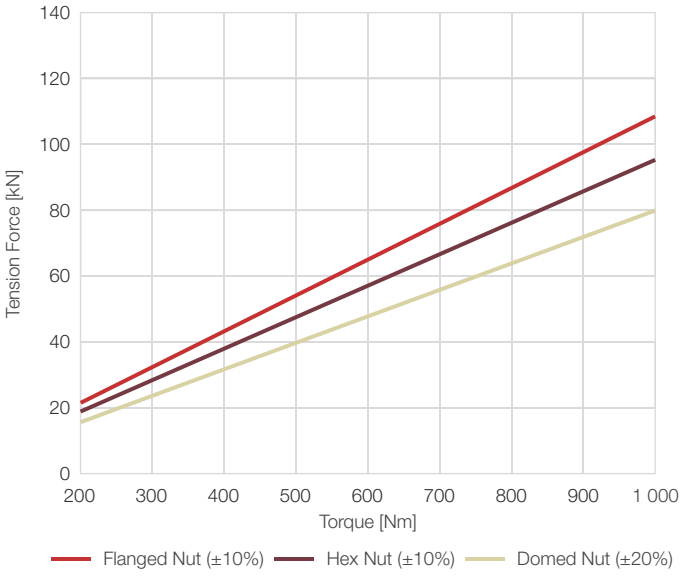
Specifications SI Units (EMEA) [1)]

Type	Nominal Diameter	Cross-Sectional Area	Yield Strength	Tensile Strength	Yield Load	Ultimate Load
[–]	[mm]	[mm²]	[N/mm²]	[N/mm²]	[kN]	[kN]
DSI Solid Bar Type 550/620 left-hand thread	20	314	550	620	173	195
	25	491	550	620	270	304
	28	616	550	620	339	382
	32	804	550	620	442	499
	40	1 257	550	620	691	779
	50	1 963	550	620	1 080	1 217
DSI Solid Bar Type 670/800 right-hand thread	18	254	670	800	170	203
	22	380	670	800	255	304
	25	491	670	800	329	393
	28	616	670	800	413	493
	30	707	670	800	474	566
	35	962	670	800	645	770
	43	1 452	670	800	973	1 162
	50	1 963	670	800	1 315	1 571

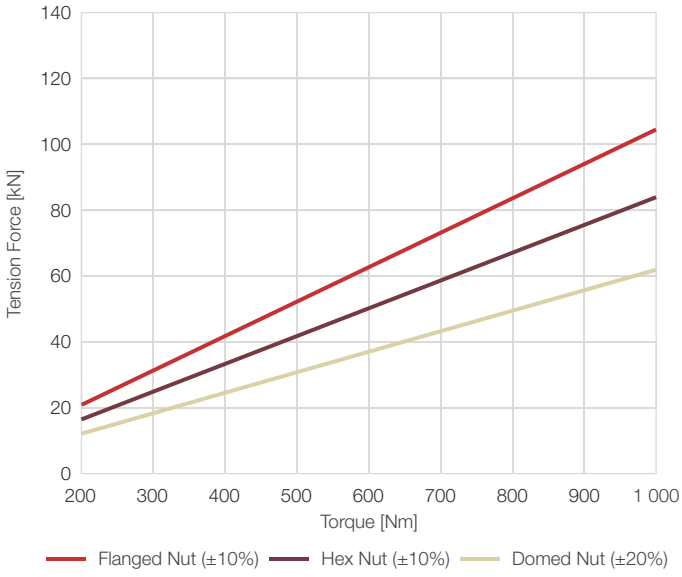
1) Alternative steel grades and diameters greater than 50 [mm] (2 [in]) available upon request.

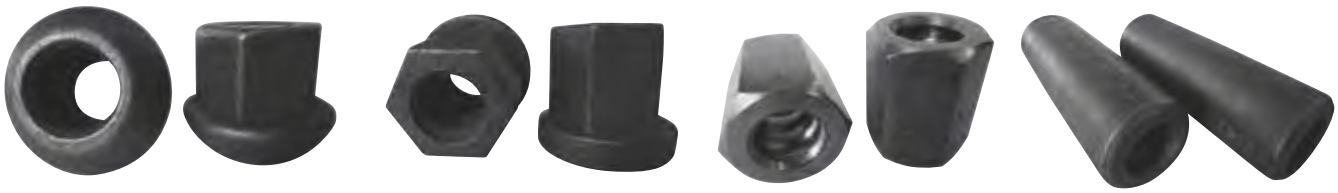
Torque-Tension Relationship

DSI Solid Bar left-hand Thread Ø 25 [mm]



DSI Solid Bar left-hand Thread Ø 28 [mm]





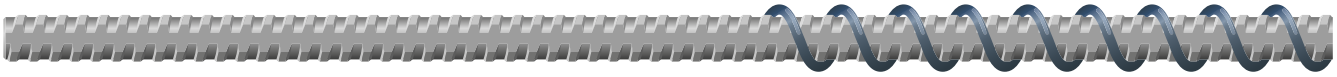
Specifications US Customary Units (North America) [1)]

Type	Designation	Maximum Outer Diameter	Cross-Sectional Area	Yield Strength	Nominal Yield Load	Nominal Weight
[–]	[–]	[in]	[in²]	[ksi]	[kip]	[lb/ft]
DSI Solid Bar Grade 75/80 left-hand thread	#6	0,86	0,44	75	33,0	1,50
	#7	0,99	0,60	75	45,0	2,04
	#8	1,12	0,79	75	59,3	2,67
	#9	1,26	1,00	75	75,0	3,40
	#10	1,43	1,27	75	95,3	4,30
	#11	1,61	1,56	75	117,0	5,31
	#14	1,86	2,25	80	180,0	7,65
DSI Solid Bar Grade 100 right-hand thread	#6	0,86	0,44	100	44,0	1,50
	#7	0,99	0,60	100	60,0	2,04
	#8	1,12	0,79	100	79,0	2,67
	#9	1,26	1,00	100	100,0	3,40
	#10	1,43	1,27	100	127,0	4,30
	#11	1,61	1,56	100	156,0	5,31
	#14	1,86	2,25	100	225,0	7,65

1) Reinforcing steel according to ASTM A615-92b and CSA G30.18M-92.

Posimix Resin Bolt

- Specially designed spring wire attached to the up hole end
- Ideal for installation of resin grouted bolts in larger diameter boreholes
- Helix features bolt centralization and improved mixing of resin cartridges
- Reduction of “gloving” effects



System Accessories

Eye Nut

Cable Guide Nut

Angle Compensation Disk

Expansion Shell

Spinners

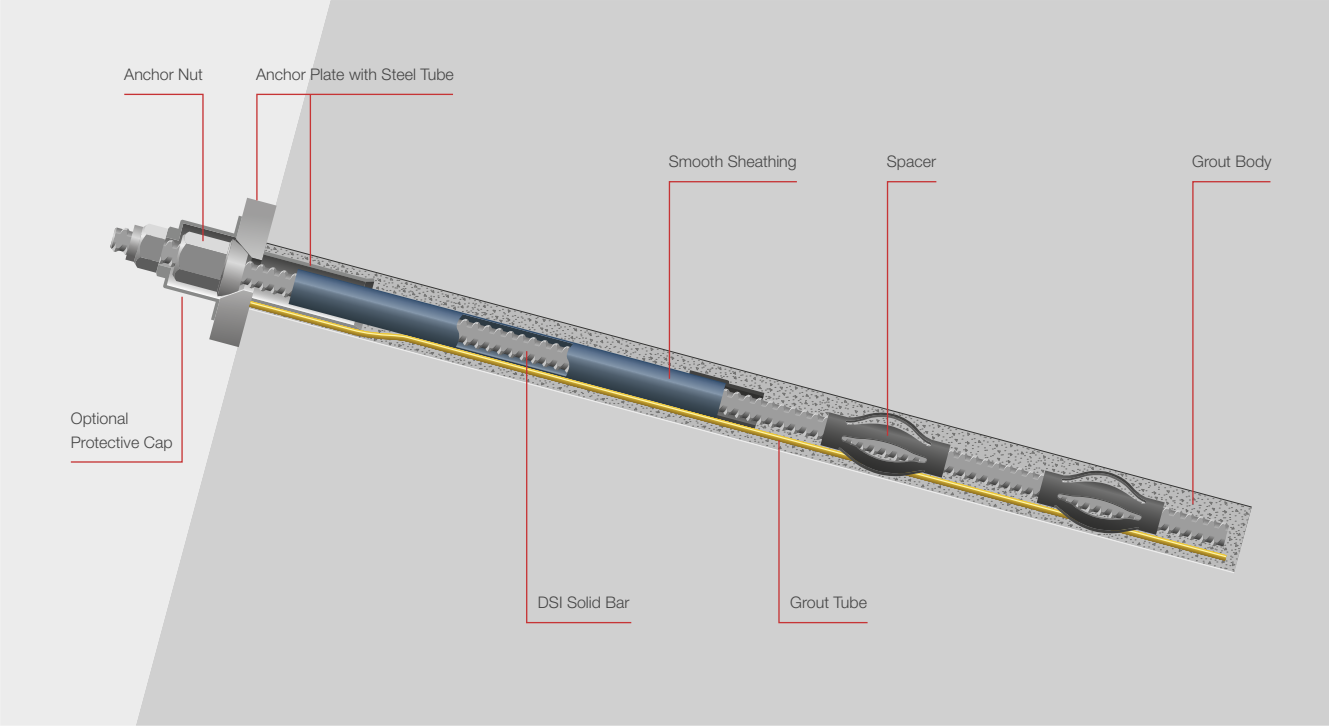
Nutrunners

Retaining Element

DSI Solid Bar Anchors

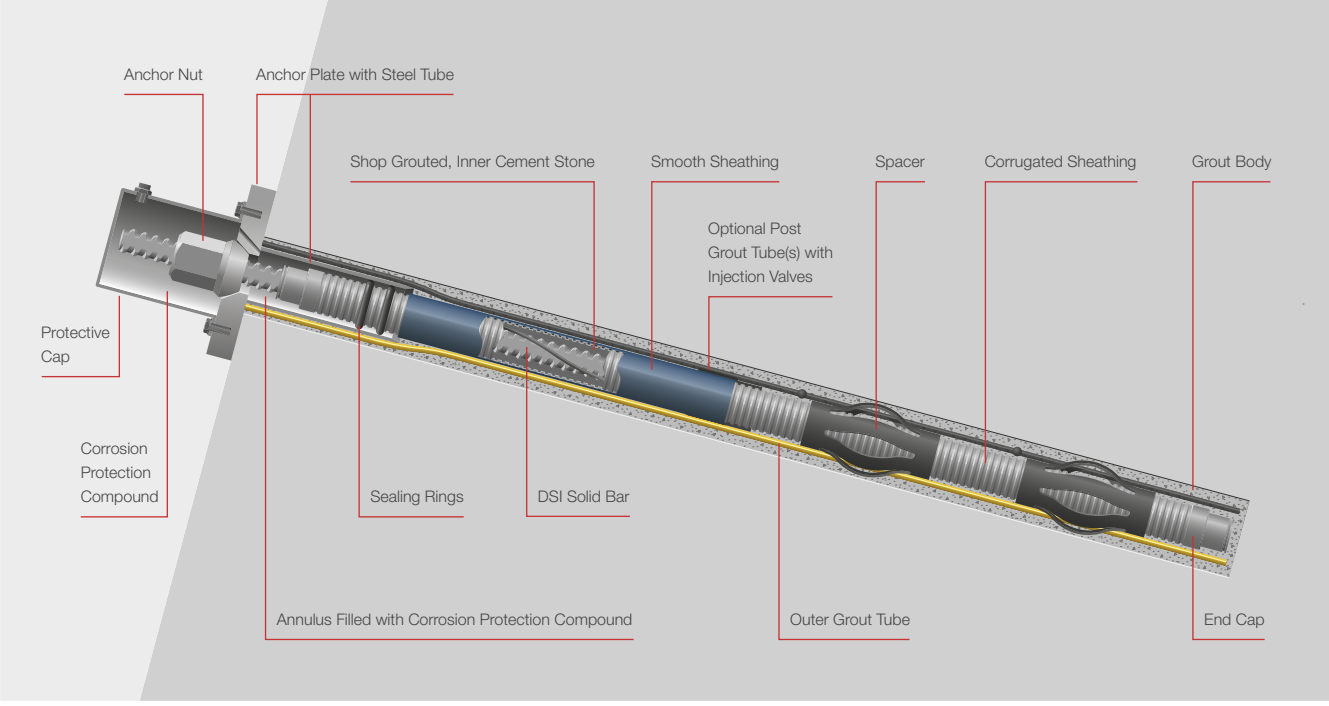
Temporary Anchors

- Corrosion protection by cement grout coverage
- Approval for temporary use



Permanent Anchors

- Double corrosion protection (DCP): pre-grouted corrugated sheathing featuring controlled crack width
- Approval for permanent use



GRP Bolts

Introduction

Glass-reinforced plastic (GRP) bolts are used as an alternative to conventional ground control elements made of steel. Thanks to the rapid development of production technologies and an increasing share of mechanical excavation, GRP systems have gained importance in Tunneling around the world.

Fields of application of GRP bolts range from cuttable bolts for mechanical excavations to injection lances or forepoling.

DSI Underground provides a diversified portfolio of GRP systems for various underground applications which is completed by longtime experience in the production and application of GRP bolts.

Main Advantages

- Lightweight system ensures an easy handling and installation
- High tensile load-bearing capacity
- Tough and durable, yet easy to cut using mechanical excavators or shearers
- Enhanced corrosion resistance
- Anti-static components – EX-proof system
- Tough and resistant thread form adjusted to the demands in the construction industry

System Description

- Composite system consisting of high-strength glass fibers and high performance resin
- German approval for underground application
- Available in different versions
  - Type CS: fully threaded solid bars
  - Type CH: fully threaded hollow bars
  - Type CR: fully threaded self-drilling hollow bars with advanced, resistant composite structure
  - Reinforcing bars and composite mesh
- Installation in combination with concrete, cement grout, anchor mortar, resin cartridges, or Mineral Bolt

System Components

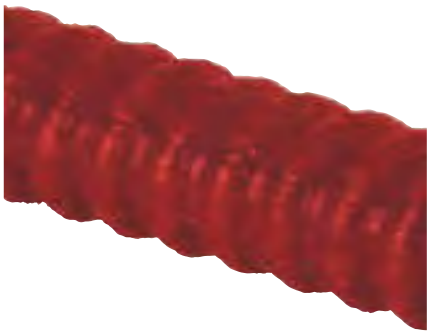
- Type CS
  - Fully threaded solid GRP bar
  - GRP plate
  - GRP nut

- Type CH
  - Fully threaded hollow bar
  - GRP plate
  - GRP nut

- Type CR
  - Single-use drill bit – different designs and dimensions available
  - Fully threaded self-drilling hollow bar
  - GRP plate
  - GRP nut

Specifications SI Units

Characteristic Value / Type [1) 2)]		Symbol	Unit	CS20-190	CS25-300	CS32-560	CH25-250	CH32-350	CR32-315
Nominal external diameter		$D_{e.nom}$	[mm]	20	25	32	25	32	32
Nominal cross-section [3)]		S_0	[mm²]	186	346	580	230	340	340
Nominal weight [3)]		m	[kg/m]	0,60	0,90	1,30	0,65	1,00	0,95
Ultimate load bar [4)]		$F_{m.nom}$	[kN]	190	300	560	250	350	315
Ultimate strength bar		$R_{m.nom}$	[N/mm²]	1 000	900	1 000	1 000	1 000	900
Ultimate elongation bar		A	[%]	2,5	1,7	2,5	2,5	2,5	1,5
Shear force bar		$F_{S.nom}$	[kN]	90	160	230	110	140	140
Modulus of elasticity		E	[N/mm²]	40 000	51 000	40 000	40 000	40 000	61 000
Ultimate load system	Steel hex nut	–	[kN]	70	170	130	100	130	140
	GRP domed nut	–	[kN]	70	70	90	70	90	105
	GRP hex nut	–	[kN]	70	170	120	100	120	200
	Steel coupling	–	[kN]	80	165	180	170	180	185
Delivery lengths [5)]		L	[m]	1,0 - 6,0					
Color code		–	[–]	BLACK	BLACK	BLACK	GREEN	GREEN	RED



Specifications US Customary Units (Alternative Types Available upon Request)

Characteristic Value / Type [1) 2)]		Symbol	Unit	CS20-190	CS25-300	CS32-560	CH25-250	CH32-350	CR32-315
Nominal external diameter		$D_{e.nom}$	[in]	0,79	0,98	1,25	0,98	1,25	1,25
Nominal cross-section [3)]		S_0	[in²]	0,29	0,54	0,90	0,36	0,53	0,53
Nominal weight [3)]		m	[lb/ft]	0,4	0,6	0,9	0,4	0,7	0,6
Ultimate load bar [4)]		$F_{m.nom}$	[kip]	43	67	126	56	79	71
Ultimate strength bar		$R_{m.nom}$	[ksi]	145	131	145	145	145	131
Ultimate elongation bar		A	[%]	2,5	1,7	2,5	2,5	2,5	1,5
Shear force bar		$F_{S.nom}$	[kip]	20	36	52	25	31	31
Modulus of elasticity		E	[ksi]	5 800	7 400	5 800	5 800	5 800	8 850
Ultimate load system	Steel hex nut	–	[kip]	16	38	29	22	29	31
	GRP domed nut	–	[kip]	16	16	20	16	20	24
	GRP hex nut	–	[kip]	16	38	27	22	27	45
	Steel coupling	–	[kip]	18	37	40	38	40	42
Delivery lengths [5)]		L	[ft]	20 - 39					
Color code		–	[–]	BLACK	BLACK	BLACK	GREEN	GREEN	RED

1) Note: all values are subject to change; other designs and dimensions are available upon request; corresponding plates according to manufacturer specifications.

2) According to manufacturer specifications or German approval for underground application.

3) Characteristic fractile value.

4) Calculated from the characteristic ultimate strength value and nominal weight, rounded.

5) Standard lengths max. 6 [m] (19,7 [ft]), customized lengths up to 11,8 [m] (38,7 [ft]) available upon request.

Technical Features

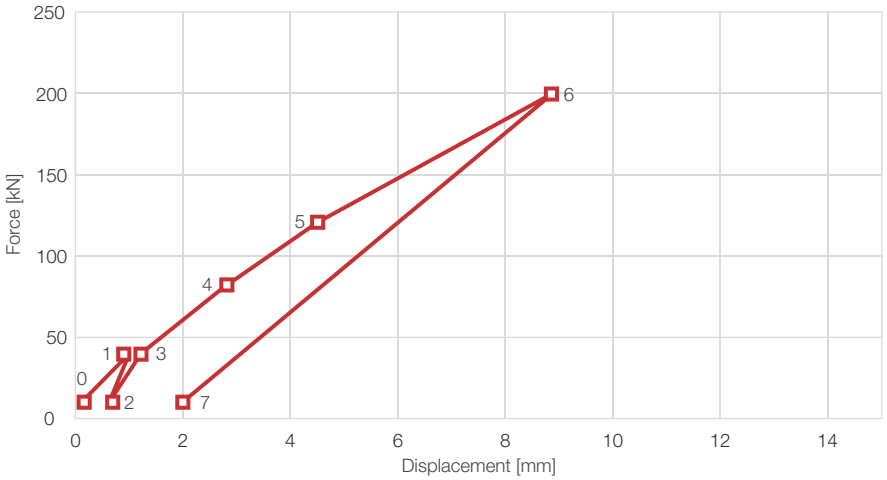
Drill Bits

- A successful installation depends on the selection of the proper drill bit
- Comprehensive drill bit portfolio for various ground conditions
- Optimized in terms of cuttability and drilling performance
- Adapted to the requirements of underground applications
- Further information on the characteristics and selection of drill bits is available in the catalogue section “DSI Hollow Bar System”

Accessories

- Steel accessories available upon request
- GRP rebars
  - Fully threaded solid GRP bar
  - Threading according to the demands for concrete reinforcing elements
  - Connectors depending on the application
  - Reinforcing cages available upon request
- GRP composite mesh
  - Bolt mesh and rockfall nets available upon request

In-Situ Pull Testing (DIN 21521-2): Load-Displacement Diagram CR32-315 with Mineral Bolt MI



Cable Bolts

Introduction

- Underground caverns
- Bolting in limited space conditions
- Reinforcement of roadways and gateways
- Bolting in the hanging wall of longwall t-junctions

Main Advantages

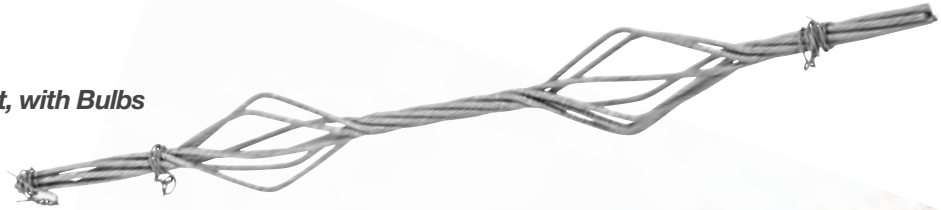
- Long cable bolts are easily displaceable in limited space
- High load-bearing capacity at a low weight per meter
- Flexible bolt lengths
- Installation using cement cartridges, resin cartridges, cement grout, or injection resin
- Different types of cable bolt tensioners available upon request

System Description

- Cable bolts are available in different versions
- Hollow or heavy-duty cable bolts available upon request

Passive Cable Bolt, Plain Version

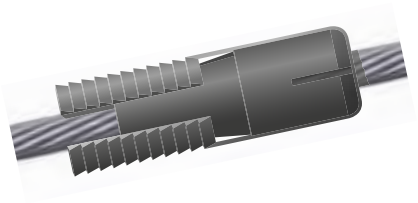
Passive Cable Bolt, with Bulbs



Hollow Cable Bolt

System Components

- End holding device
  - Single strand fish hook
- Expansion shell
  - Spring-loaded
- 7 wire prestressing strand
  - Uncoated, low relaxation strand
  - 1 center wire and 6 outer wires
  - Plain or bulbed version
  - Different customer-specific lengths
  - Greased strands with free lengths available upon request
- Plate
  - Different designs and dimensions available upon request
- Domed barrel and wedge cable grip
  - Domed barrel
  - 3 pcs. wedge
  - Optional plastic cap
- Injection and breather tubes
  - Standard versions 13 x 2 [mm] (0,5 x 0,08 [in]) and 16 x 2 [mm] (0,6 x 0,08 [in])
  - Alternative designs and dimensions available upon request
- Packaging
  - Loose bundles
  - Different reel delivery options upon request
- Further information on cable bolts can be found in local technical product brochures



Specifications SI Units (EMEA)

Characteristics / Type	Unit	CB15.3		CB15.7	
Nominal diameter	[mm]	15,3		15,7	
Cross-section	[mm²]	140		150	
Weight	[kg/m]	1,09		1,17	
Yield strength $R_{p0.1}$	[N/mm²]	1 560	1 680	1 560	1 680
Tensile strength	[N/mm²]	1 770	1 860	1 770	1 860
Yield load $F_{p0.1}$	[kN]	218	229	243	246
Ultimate load	[kN]	248	260	266	279

Accessories

- De-bonding sleeves
- Spin nut versions for tensioning
- DSI Inject Systems and FASLOC® resin cartridges
- Tensionable cable bolt
  - Press sleeve
  - Metric or UNC thread
  - Tension nut
- Cable bolt tensioning jack
- Cable bolt expansion shell
- Dog bone coupling for slings or trusses
- Load indicators
- Galvanized system components available upon request
- Packers and borehole sealings available upon request

DCP TEN Cable Bolt (AU)

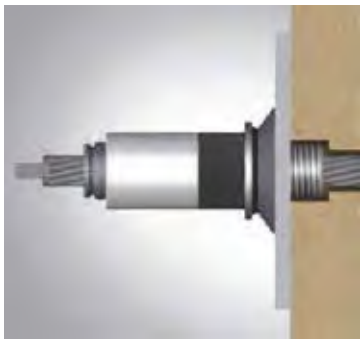
- Flexible HI-TEN cable bolt
- Heavy-duty combination cable bolt version
- Point anchorage: expansion shell
- Post grouting via the integrated grout bell
- Corrugated HDPE sleeve for load transfer and corrosion protection
- Barrel and wedge assembly with integrated grout bell for collar fastening
- Further information can be found in local technical product brochures

Characteristics / Type	Unit	DTC23
Nominal diameter	[mm]	23,5
Weight	[kg/m]	2,87
Yield load $F_{p0,1}$	[kN]	480
Ultimate load	[kN]	590
Ultimate elongation	[%]	3 - 4
Borehole diameter range	[mm]	45 - 50

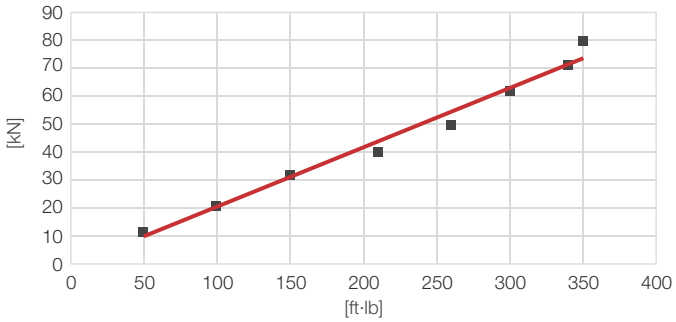
EZI TEN Cable Bolt (AU)

- Dolly tensioned HI-TEN cable bolt with a strand locker
- Installation in Ø 28 [mm] (1,1 [in]) boreholes including a 150 [mm] (5,9 [in]) long Ø 42 [mm] (1,7 [in]) reaming section
- Point anchorage: resin cartridge
- Barrel and wedge assembly including threaded tensioning system for mechanized bolting
- Quick and simple installation procedure – no special hydraulic tensioner required
- Installation with a 56 [mm] (2,2 [in]) AF dolly
- Further information can be found in local technical product brochures

Characteristics / Type	Unit	ETC23
Nominal diameter	[mm]	23,5
Weight	[kg/m]	2,87
Yield load $F_{p0,1}$	[kN]	480
Ultimate load	[kN]	590
Ultimate elongation	[%]	3 - 4
Borehole diameter	[mm]	28/42
Tail length	[mm]	180 - 250
Max. diameter bolt head	[mm]	56
Max. diameter tensioning dolly	[mm]	74



Torque vs. Tension



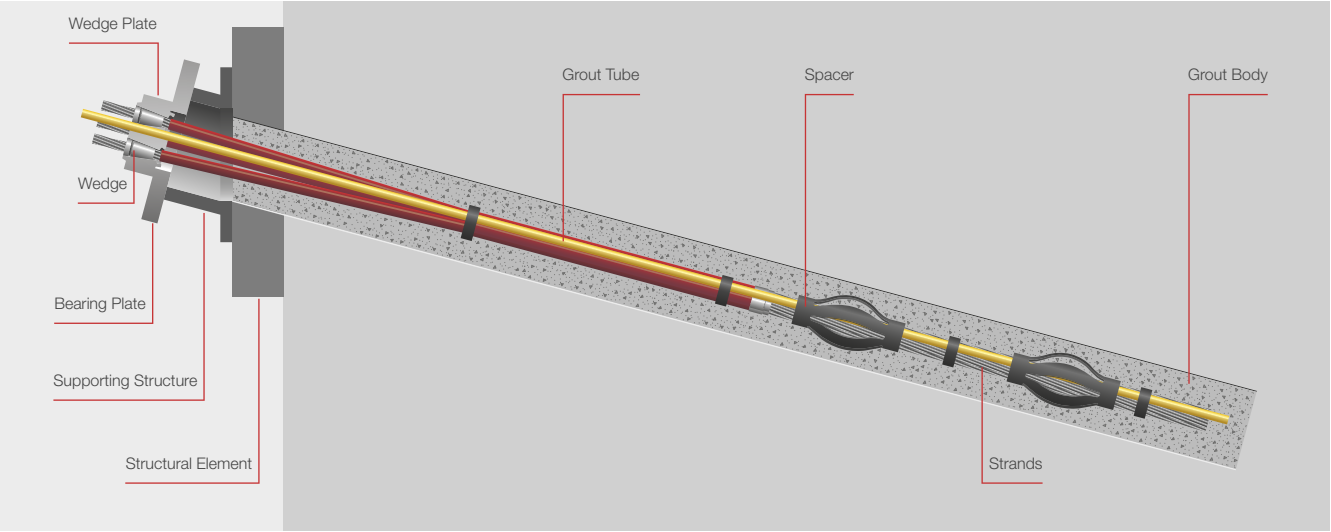
HI-TEN Hollow Cable Bolt (AU)

- High tension flexible hollow cable with centre tube
- Hex drive for resin cartridge mixing and grouting lance adaption
- Point anchorage: resin cartridge or spring-loaded expansion shell
- Barrel and wedge assembly for collar fastening
- Integrated top down cement grouting (thixotropic grout) feature through the centre tube in the cable
- Default grout release bulb with resin dam
- Optional bulbs for enhanced load transfer
- Further information can be found in local technical product brochures

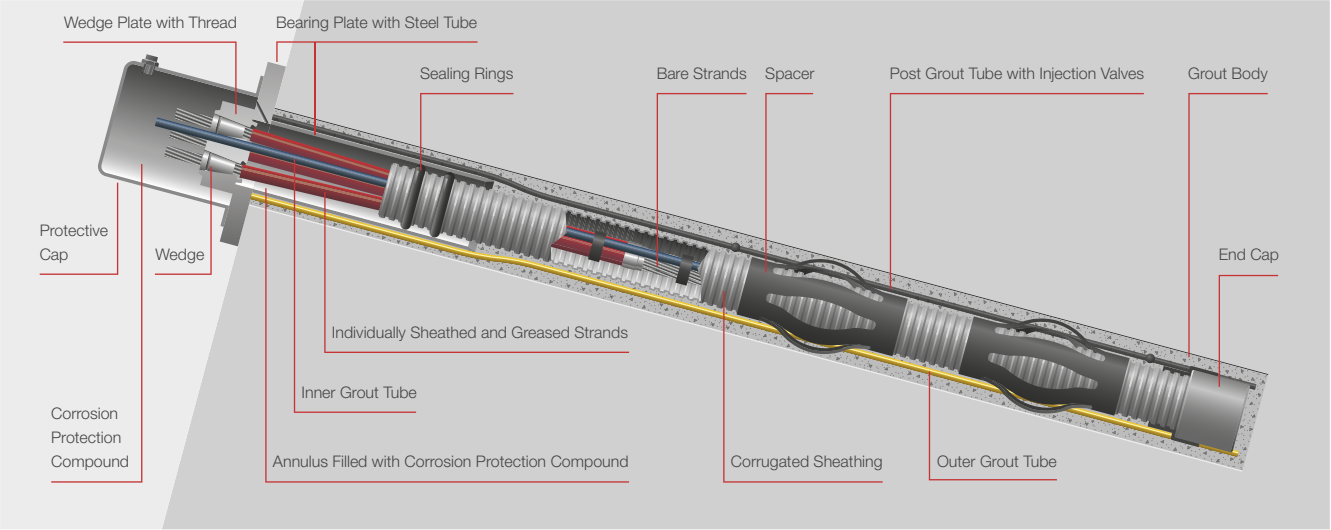
Characteristics / Type	Unit	HTC28
Nominal diameter	[mm]	28
Weight	[kg/m]	2,8
Yield load $F_{p0,1}$	[kN]	550
Ultimate load	[kN]	605

Strand Anchors

Temporary



Permanent



Cable Bolt Tensioners

Introduction

Cable bolt tensioners are used for prestressing or active pre-tensioning of cable bolts. These devices for use in underground operations are characterized by low weight, robust construction, and user-friendliness.

DSI Underground provides different systems of cable bolts and cable bolt tensioners, depending on individual applications.

Specifications

Characteristic Value / Type	Unit	CBT-125	CBT-300	TEN-22
Tension force	[kN]	125	320	215
	[kip]	28	72	48
Weight	[kg]	10	16	12
	[lb]	22	35	26

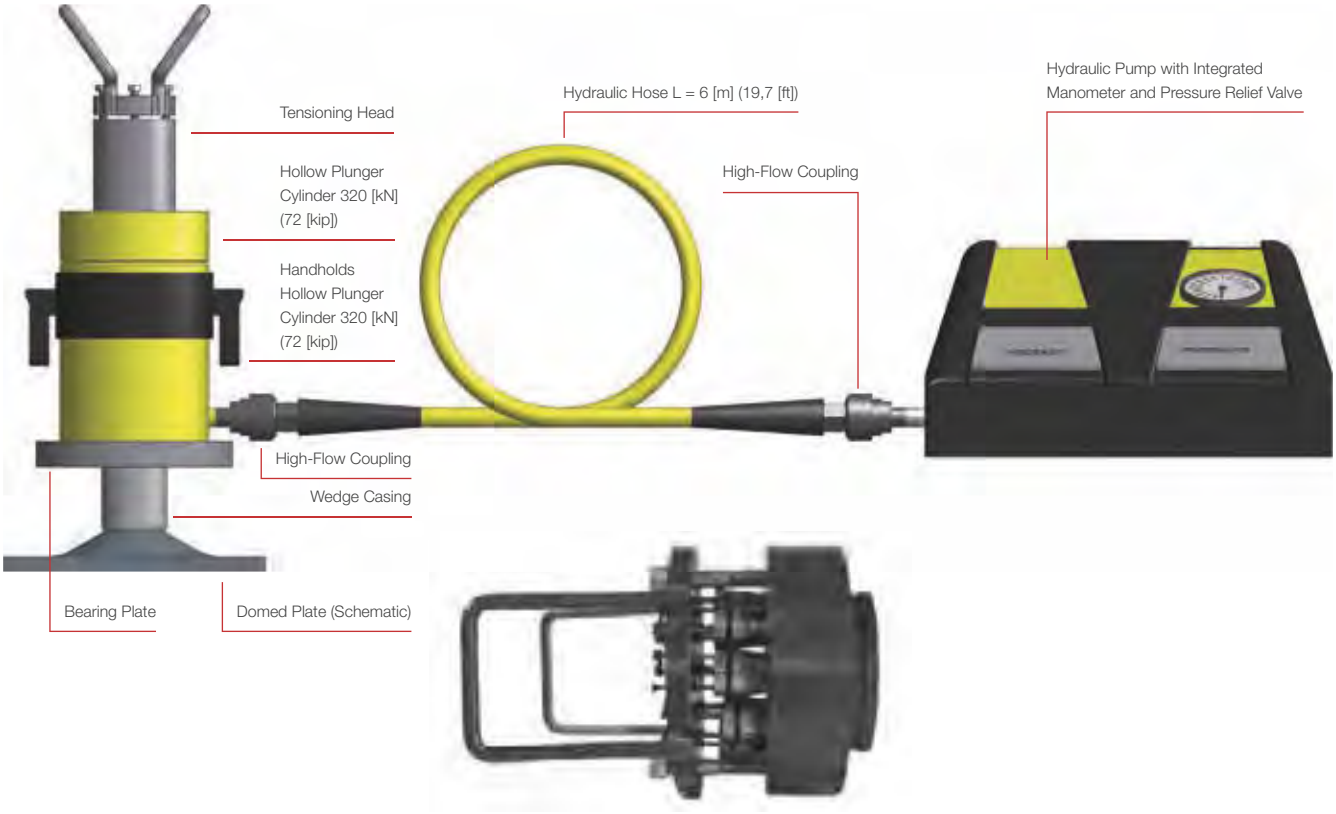
Fields of Application

- Pre-tensioning of type 0,6", CB15,3, and CB15,7 cable bolts
- Prestressing of cable bolts with free length
- When tensioning or pre-tensioning, the forces that are permitted for the cable bolts in use must be observed

Installation Procedure Passive Cable Bolt

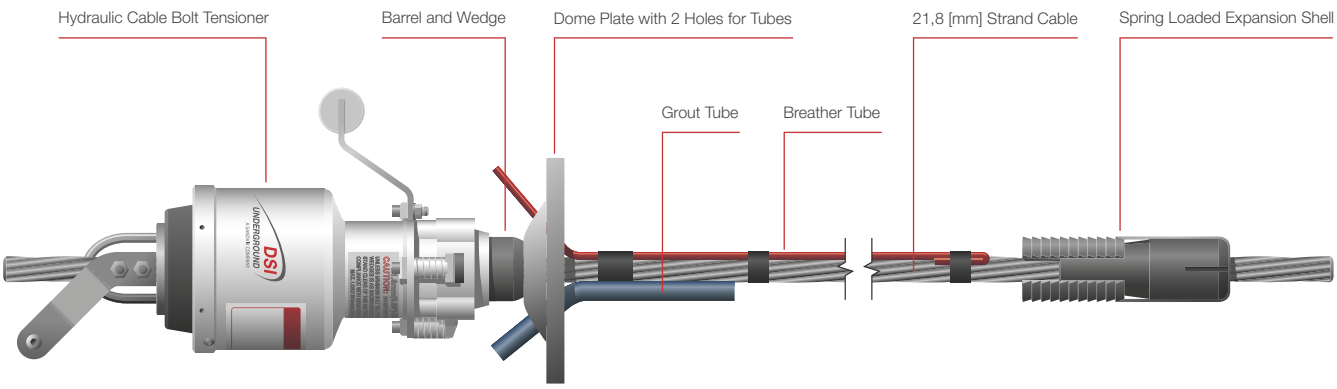
- Borehole drilling
- The choice of the borehole diameter depends on the drilling machinery, the cable bolt length, and the bonding medium
- Version A: filling of the borehole with cement grout or resin cartridges, then insertion of the cable bolt
- Version B: insertion of the cable bolt with factory-installed injection hose, subsequent injection with cement grout or injection resin
- Anchorage of the head: plate and wedge or press sleeve
- Prestressing of the barrel and wedge assembly with a cable bolt tensioner

System Components Type CBT-300



System Components Type CBT-125

System Components Type TEN-22



Continuous Friction

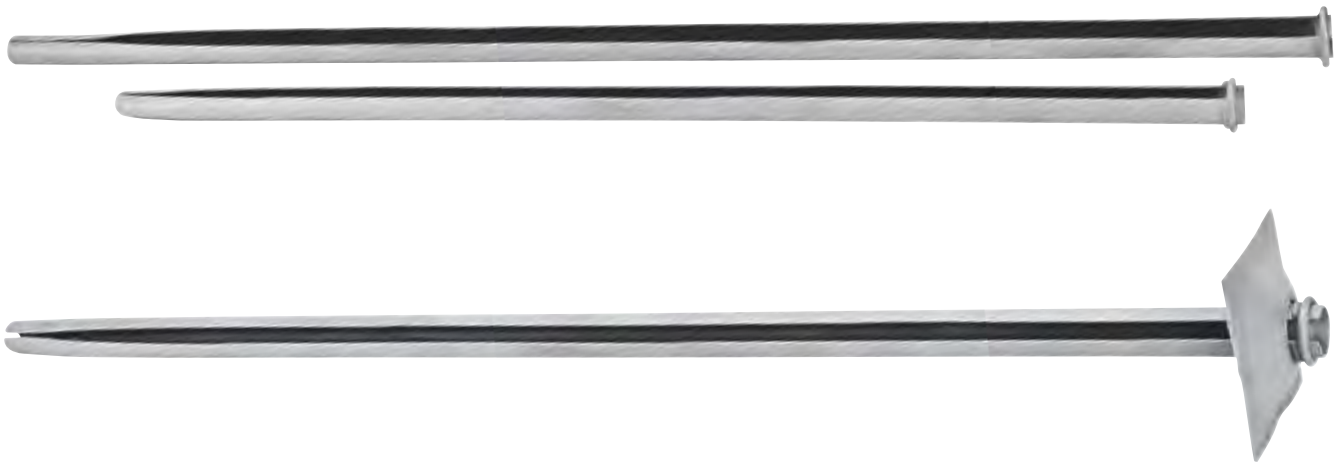
Friction Stabilizers

Introduction

Friction stabilizers are mainly used for rock reinforcement in underground mining. The shaft of the friction stabilizer consists of a metal strip which is folded to form a slotted tube. The bolt is installed into a borehole by applying impact energy. The borehole features a slightly smaller diameter than the outer diameter of the bolt tube.

The principle of this bolting system is based on the bond between the borehole and the tubular bolt shaft, caused by applying force onto the borehole wall, which generates a frictional resistance in axial direction.

Recently, a self-drilling friction bolt system, the POWER SET self-drilling friction bolt, has been developed by DSI Underground in addition to conventional friction stabilizers.



Main Advantages

- Easy and fast installation procedure
- Both hand-held and mechanized installation is possible
- Immediate load-bearing capacity after installation
- Low sensitivity to ground displacements

Technical Features

- Deviations in actual borehole diameters affect the load-bearing capacity of friction stabilizers
- The actual load-bearing capacity depends on existing ground conditions
- Required borehole diameters must be adapted when installed in soft or highly jointed rock mass

System Components

- Friction stabilizer tube
  - Slotted steel tube
  - Tapered on the far end
  - Welded-on collar ring
- Plate
  - Default domed version
  - Different designs and dimensions available upon request
- Galvanized or coated system components available upon request

Specifications SI Units

Characteristics / Type [1]	Symbol	Unit	FS33	FS39	FS46
External diameter [2]	D_e	[mm]	33	39	46
Nominal weight [2]	m	[kg/m]	1,5	1,8	2,9
Ultimate load [2]	F_m	[kN]	105	110	150
Yield strength [3]	R_e	[N/mm²]	410	410	410
Ultimate strength [3]	R_m	[N/mm²]	520	520	520
Elongation [3]	A	[%]	10	10	10
Recommended drill bit diameter	B	[mm]	30 - 32	36 - 38	41 - 44
Delivery lengths [4]	L	[mm]		600 - 4 000	

Specifications US Customary Units

Characteristics / Type [1]	Symbol	Unit	FS33	FS39	FS46
External diameter [2]	D_e	[in]	1,3	1,5	1,8
Nominal weight [2]	m	[lb/ft]	1,0	1,2	1,9
Ultimate load [2]	F_m	[kip]	24	25	34
Yield strength [3]	R_e	[ksi]	59	59	59
Ultimate strength [3]	R_m	[ksi]	75	75	75
Elongation [3]	A	[%]	10	10	10
Recommended drill bit diameter	B	[in]	1,2 - 1,3	1,4 - 1,5	1,6 - 1,7
Delivery lengths [4]	L	[in]		24 - 158	

1) Note: all values are subject to change. Other dimensions, steel grades, and compliant bolt plates available upon request.

2) Nominal value.

3) According to primary material supplier information; modulus of elasticity: 210 000 [N/mm²] (30 450 [ksi]).

4) Off-size lengths are available upon request.

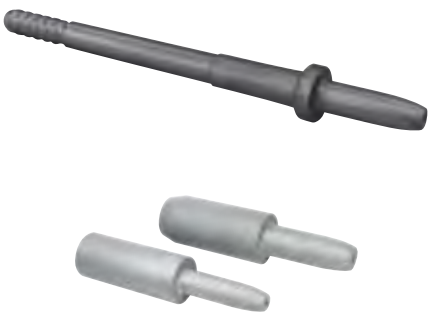
Further information on friction stabilizer bolts can be found in local technical product brochures.

Installation Procedure

- Drilling of a borehole according to specifications; borehole lengths should exceed the friction stabilizer length by approx. 150 [mm] (6 [in])
- Insertion of the friction stabilizer plus bolt plate onto the driver tool
- Launch of the friction stabilizer into the borehole, either manually or mechanized
- Installation into the borehole using percussion from the rock drill via a driving tool onto the collar of the friction stabilizer until the plate is firmly pressed against the excavation surface
- Note: friction stabilizers should be installed as perpendicularly as possible to the excavation surface

Installation Accessories

- Straps or mesh
- Driver tools for hand-held and mechanized bolters



OMEGA-BOLT® Expandable Friction Bolts

Introduction

The main application of the OMEGA-BOLT® expandable friction bolt is temporary rock reinforcement for underground applications.

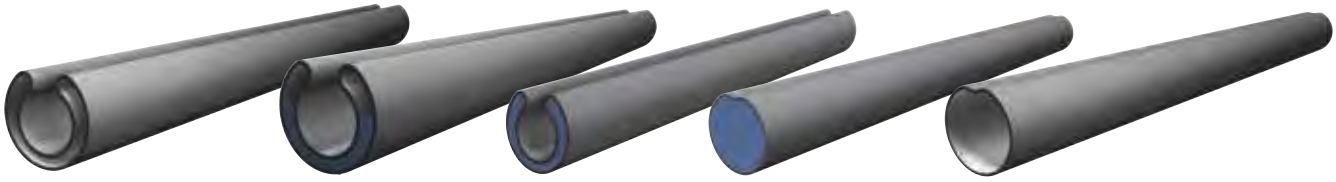
Bonding forces between the friction bolt and the ground are caused by form closure (mechanical interlocking) and friction transfer between the borehole wall and the bolt, which is expanded by hydraulic pressure.

Main Advantages

- Immediate full load-bearing capacity over the entire installed bolt length
- Trouble-free installation in water-bearing boreholes
- Low sensitivity against vibrations caused by blasting works
- Ability to maintain load-bearing capacity even when undergoing deformations
- Safe and easy installation
- No additional building materials required for installation
- Flexibility in case of varying borehole diameters
- Quality check during every single installation
- Different customized high-pressure pumps available

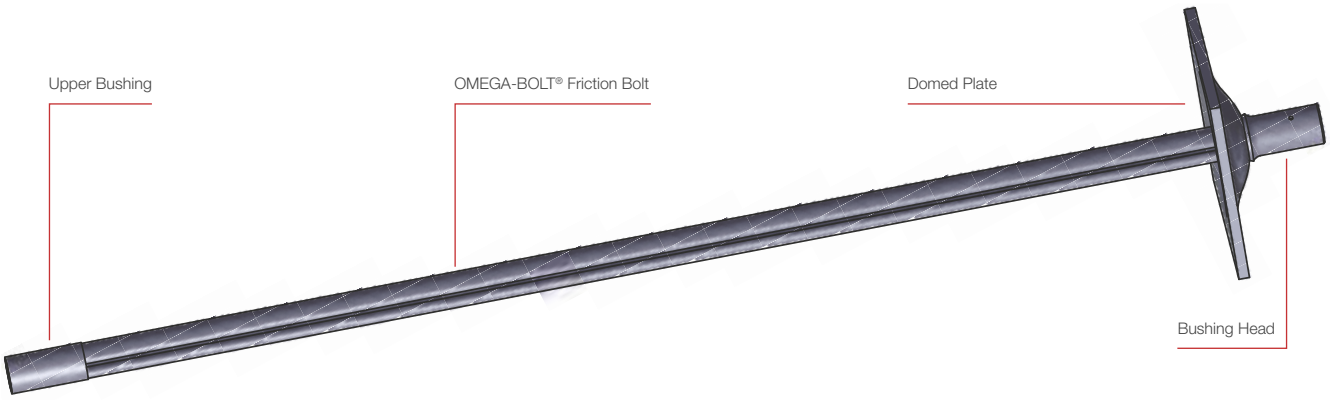
System Description

- Manual or mechanized installation by expansion of the omega-shaped profile with high-pressure water
- Frictional load transfer and mechanical interlocking between bolt and borehole
- Adjustment of the expanded profile to irregularities of the borehole wall and variations in borehole diameter
- OMEGA-BOLT® version “+” provides improved elongation properties
- Galvanized or epoxy coated versions available upon request



System Components

- Bushing head
  - Flared, with inflation hole
- Domed plate
  - Different designs and dimensions available upon request
- OMEGA-BOLT® profile
- Upper bushing



Specifications SI Units

Characteristic Value / Type [1]	Unit	EFB-120	EFB-160	EFB-200	EFB-240	EFB-120+	EFB-240+
Yield load [2]	[kN]	100	140	180	220	90	170
Nominal ultimate load [2]	[kN]	120	160	200	240	120	230
Characteristical ultimate elongation [2]	[%]	10	10	10	10	30	30
Nominal ultimate elongation [2]	[%]	6	6	6	6	20	20
External diameter Ω profile [3]	[mm]	26	36	36	36	27,5	36
External diameter original tube	[mm]	41	54	54	54	41	54
Wall thickness	[mm]	2	2	2,5	3	2	3
Diameter bushing head	[mm]	30	41	41	41	30 / 36	41 / 48
Diameter upper bushing	[mm]	28	38	38	38	28	38
Required borehole diameter	[mm]	32 - 40	45 - 53	45 - 53	45 - 53	32 - 39	43 / 52
Optimum borehole diameter	[mm]	36 - 39	48 - 52	48 - 52	48 - 52	35 - 38	45 / 51
Inflation pressure	[bar]	260	260	300	300	300	300
Delivery lengths [4]	[m]	2,0 to 12,0				1,0 - 8,0	

Specifications US Customary Units

Characteristic Value / Type [1]	Unit	EFB-120	EFB-160	EFB-200	EFB-240	EFB-120+	EFB-240+
Yield load [2]	[kip]	22	31	40	49	20	38
Nominal ultimate load [2]	[kip]	27	36	45	54	27	52
Characteristical ultimate elongation [2]	[%]	10	10	10	10	30	30
Nominal ultimate elongation [2]	[%]	6	6	6	6	20	20
External diameter Ω profile [3]	[in]	1,0	1,4	1,4	1,4	1,1	1,4
External diameter original tube	[in]	1,6	2,1	2,1	2,1	1,6	2,1
Wall thickness	[in]	0,08	0,08	0,10	0,12	0,08	0,12
Diameter bushing head	[in]	1,2	1,6	1,6	1,6	1,2 / 1,4	1,6 / 1,9
Diameter upper bushing	[in]	1,1	1,5	1,5	1,5	1,1	1,5
Required borehole diameter	[in]	1,3 - 1,6	1,8 - 2,1	1,8 - 2,1	1,8 - 2,1	1,3 / 1,5	1,7 / 2,0
Optimum borehole diameter	[in]	1,4 - 1,5	1,9 - 2,0	1,9 - 2,0	1,9 - 2,0	1,4 / 1,5	1,8 / 2,0
Inflation pressure	[psi]	3 770	3 770	4 350	4 350	4 350	
Delivery lengths [4]	[m]	6,6 - 39,4				3,3 - 26,2	

1) Note: OMEGA-BOLT® expandable friction bolts with different characteristic values are available upon request.

2) Expanded profile.

3) Tolerance: +1 [mm] (+ 0,04 [in]).

4) Off-size lengths are available upon request.

Installation Procedure

1. Borehole drilling.

2. Connection to the installation chuck and insertion of the OMEGA-BOLT® into the borehole.

3. Expansion of the OMEGA-BOLT® with high-pressure water.

4. De-coupling from the chuck after the OMEGA-BOLT® is fully inflated.

OMEGA-BOLT® High-Pressure Pumps

System Description

The installation equipment for the OMEGA-BOLT® consists of the following components:

- OMEGA-BOLT® high-pressure pump (water pump and motor)
- High-pressure hose
- Setting arm with setting head and chuck

After insertion of the OMEGA-BOLT® into the borehole, the setting arm is fitted to the bolt's head. By operating the valve lever on the setting arm, the bolt is hydraulically expanded (unfolded) using high-pressure water, which is induced into the inside of the folded bolt tube. After reaching the defined maximum setting pressure, the valve lever is released and the setting head is pulled away from the bolt's head.

Main Advantages

- Tough design and easy handling
- Fast installation due to high pump performance
- Optimum expansion of the OMEGA-BOLT® is ensured
- Alternative high-pressure pumps available upon request
- OMEGA-BOLT® pull test kit available upon request

Specifications Electric Pumps (EMEA)

Characteristics	Unit	Type 300E	Type VA300
Dimensions (L x W x H)	[mm]	800 x 400 x 455	1 200 x 460 x 530
Weight	[kg]	90	130
Max. flow rate	[L/min]	21	13
Operating pressure [1]	[bar]	300	
Max. operating pressure	[bar]	320	310
Power supply [2]	[V]	3 ~ 400	
Nominal power [2]	[kW]	11	7,5
Electrical connection [2]	[A]	25	14,3
Pumping rotation speed	[rpm]	1 400	1 450

1) Required tube connection 3/4", water connection pressure 2 [bar] (29 [psi]).

2) According to IEC 60309 (not CSA or OHSA approved). Other electric pumps are available upon request.

Mechanical Anchors

Introduction

Mechanical anchors have been used in underground construction for more than a century. They have been extensively tested and examined during various projects.

However, use of a mechanical anchor is limited to stable borehole and ground conditions – a point anchorage is unfavorable compared to a continuously bonded bolt system.

Soft ground conditions require application of speciality expansion shells, which are larger in size and optimized in regards to wing (leave) design.

Furthermore, quality control of the borehole diameter range is key in application, as over- or undersized boreholes influence the performance of mechanical anchors as well. During the tensioning process, the torque-tensioning ratio for each mechanical anchor system must be reviewed prior to application.

When ground and boundary conditions allow the use of mechanical anchors, this system is a low-cost and effective ground support element. Recently, the use of resin cartridge assisted mechanical anchors has gained additional attention.

Mechanical Rebar Anchors

Main Advantages

- Simple handling and optimized installation time
- Immediate load-bearing capacity
- Field-proven and reliable anchors
- Unproblematic installation in aquiferous boreholes
- Optimized ratio of anchor force vs. borehole diameter

System Components

- Round or threaded rebar steel
- Forged or threaded (TBE) versions
- Steel expansion shell
  - Different versions available upon request
  - Optimized in regards to the given borehole diameter
- Anchor shaft (tendon): DSI Solid Bar or rebar version
- Plate
  - DSI Solid Bar mechanical anchor: flat plate with conical through-hole
  - Mechanical rebar anchor: domed plate with round or long hole
- Nut
  - One-sided convex hexagonal nut, self-locking nut, or domed nut
  - Spherical washers and driver tools available upon request
- Other dimensions, steel grades, and galvanized versions are available upon request
- Further information on mechanical anchors can be found in local technical product brochures

Specifications Mechanical Rebar Anchors

– SI units
  - Smooth or ribbed reinforcing steel
  - Steel grade B 500 B according to DIN 488-1 or OENORM B 4700; alternative steel grades available upon request
  - Standard bar sizes: 16 [mm] and 20 [mm]
  - Different expansion shell types and diameters available upon request
  - Forged head versions available

– US customary units
  - Standard sizes 5/8", 3/4", and 7/8"
  - In accordance with ASTM F432 or CSA M430 specifications

Installation Procedure

– Drilling of a borehole in accordance with the specifications, approx. 150 [mm] (6 [in]) longer than the mechanical anchor when installed

– Insertion of the readily assembled mechanical anchor into the borehole – the expansion shell must fit tightly into the borehole

– Pre-tensioning with an impact screw driver or adequate driver tool

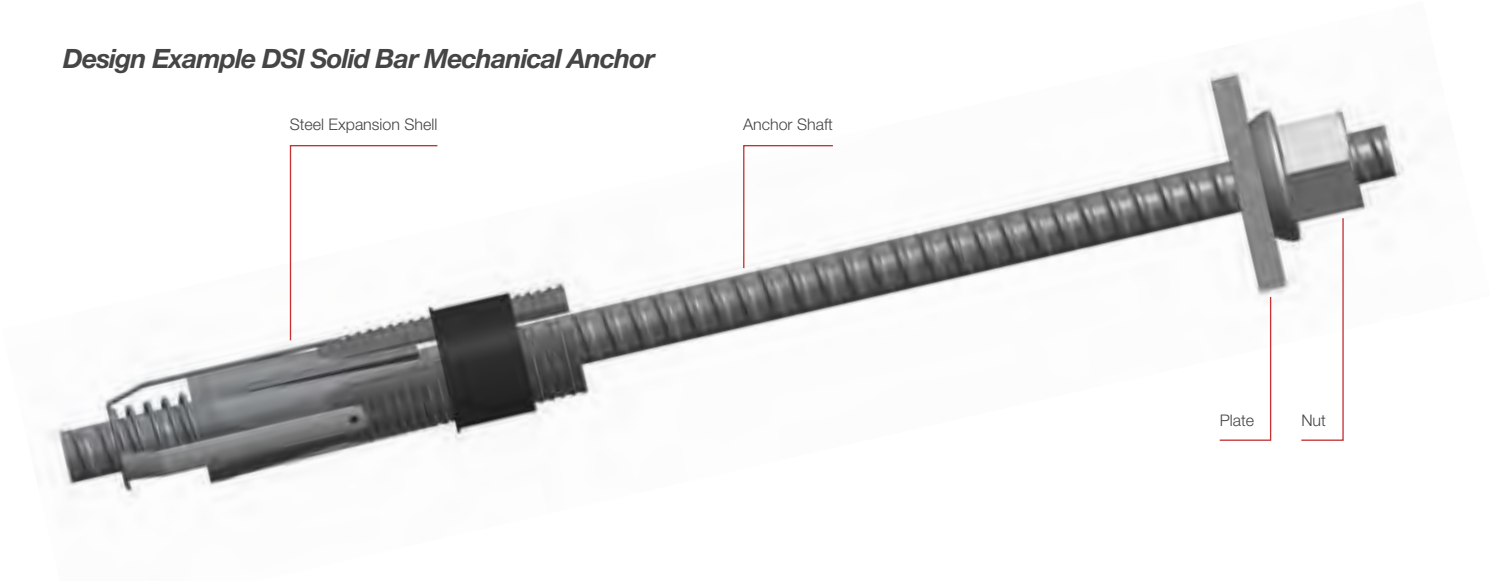
– Optional post grouting using a factory-fitted injection hose

DSI Solid Bar Mechanical Anchor

System Description

- Continuous threaded DSI Solid Bar allows flexible length adjustments and posterior extension on site
- Expansion sleeves are available for different borehole diameters
- German approval for underground application

Design Example DSI Solid Bar Mechanical Anchor



Specifications (EMEA)

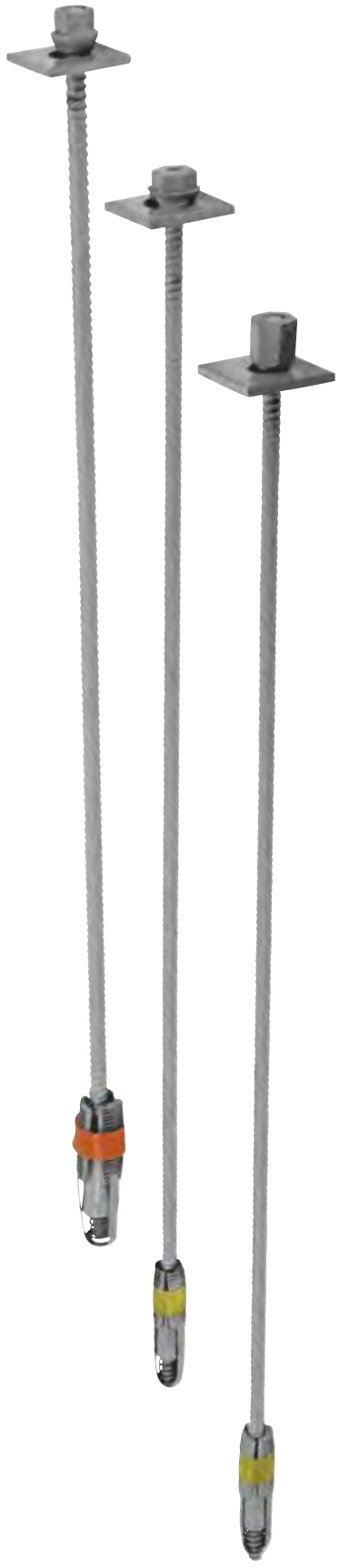
Characteristics [1]	Unit	KS-145	KS-190
Nominal diameter	[mm]	16,2	18
Nominal weight	[kg/m]	1,62	2,00
Nominal cross-section	[mm²]	207	254
Yield strength [1]	[N/mm²]	450	670
Tensile strength [1]	[N/mm²]	700	800
Ultimate load [2]	[kN]	145	190
Ultimate elongation A_5 [1]	[%]	15	15
Nut version [3]	[–]	S, H	K
Borehole diameter [4]	[mm]	34 - 36	44 - 47

1) Steel tendon (anchor shaft).

2) Anchor system: anchor bar, plate, and nut.

3) H = hex nut, one-sided convex seat; S = stop nut; K = domed nut.

4) Standard version expansion shell.



Energy-Absorbing

Introduction

Challenging ground conditions lead to the usage of bolt systems that feature an enhanced energy absorbing ability. Compared to default bolt systems, they can accommodate significantly larger deformations without failure.
Among experts, there are three different types of application:

Large deformations within a long period of time – swelling ground

A significant volume increase of the ground over time initiated by water commonly occurs in clayey environments and is driven by water (moisture) inflow. Therefore, water flushing is not the preferred method for borehole drilling. Application of friction type bolts or bolting resin is limited as well. Energy-absorbing bolts for this ground type require a high plastic elongation of the tendon and/or a yielding bolt head.

Large deformations within a short period of time – squeezing ground

In squeezing ground, significant deformations occur shortly after excavation. Here, bolt systems which can accommodate large displacements without failure within the first hours and days of installation are required. Overloaded zones often require installation of longer (coupled) bolt systems, yielding bolt heads with load indicators are commonly used to ensure a safe underground working environment.

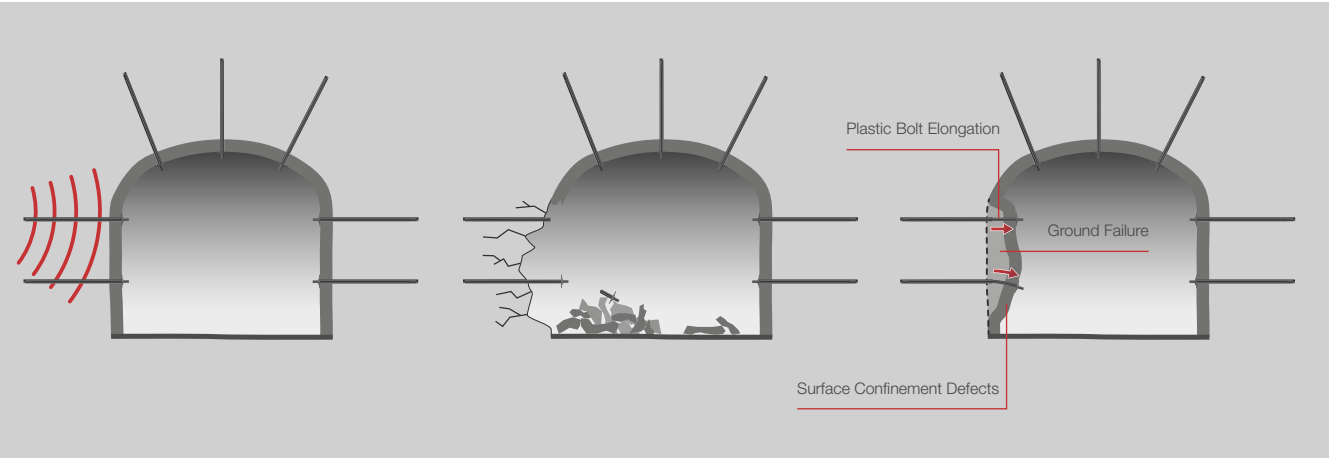
Dynamic impacts – micro-seismic events (rock bursts)

Sudden release of energy occurs in highly stressed rock, leading to micro-seismic events called rock bursts.
The energy-absorbing mechanism of bolts for dynamic impacts is commonly based on bolt tendons with a smooth or de-bonded section, which allows a high degree of energy absorption in a defined area. This requires use of a steel grade featuring high plastic elongation. Alternatively, modified friction type bolts that can accommodate large displacements in a controlled failure mode in terms of sliding are another popular bolt system for rock burst conditions.

Besides installation of energy-absorbing bolts, further special support measures such as energy-absorbing surface support (energy-absorbing plates, mesh, etc.) or special passive support systems such as LSC™ Elements are required.

Source: ITAtech Activity Group Support (2018, work in progress)

Dynamic Impacts



– A sudden micro-seismic event (rock burst) occurs in a tunnel secured by bolts, shotcrete, and wire mesh

– Default bolt systems with a limited energy-absorbing ability fail under the dynamic load impact, leading to concurrent ground failure

– Energy-absorbing bolts which are designed for dynamic impacts are yielding and absorb the energy without failure

Solid-Bars – Dynamic Posimix

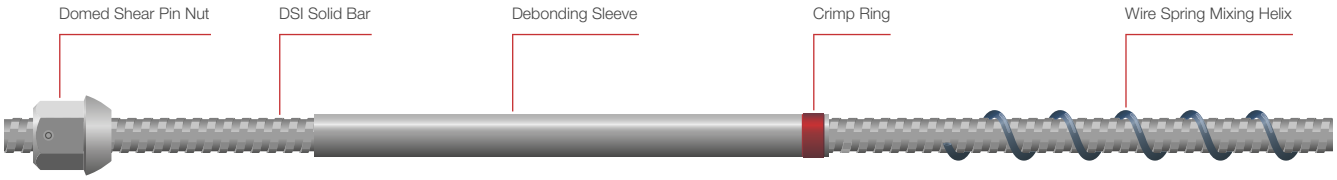
Main Advantages

- Use of the proven DSI Solid Bar System
- Installation of resin-grouted bolts in larger-diameter boreholes
- Centralized installation and enhanced mixing results by special helix system
- Proven performance by extensive testing on 2,4 [m] (8 [ft]) long bolts: Western Australian School of Mines (WSAM, AU) and Central Mining Institute Katowice (CMI, PL)

System Description

- All-threaded high-strength rebar with optional V-cut
- Central de-bonded bolt section (variable length)
- Mixing helix for resin cartridges
- Domed shear pin nut
- Fully grouted with FASLOC® resin cartridges
- Dynamic Posimix bolts with increased load-bearing capacity available upon request

System Components



Specifications (EMEA)

Characteristics	Unit	T20
Nominal diameter	[mm]	20
Nominal weight	[kg/m]	2,5
Nominal cross-section	[mm²]	300
Elongation A_5	[%]	15
Yield strength	[N/mm²]	650
Tensile strength	[N/mm²]	755
Yield load	[kN]	195
Ultimate load	[kN]	227

Further information can be found in local technical product brochures.

Dynamic Drop Test Results

WSAM

De-Bonded Length	Impact Energy	No. of Drops without Failure	Velocity	Test Configuration
[m]	[kJ]	[1]	[m/s]	[–]
1,4	19	3	4,81	Load on plate (continuous tube)
	25	2	5,52	Load on plate (continuous tube)
	30	0	5,52	Load on middle section (split tube)
	30	1	5,11	Load on plate (continuous tube)
	30	1	5,11	Load on middle section (split tube)

CMI

De-Bonded Length	Impact Energy	Deformation at Discontinuity	Demand Category Application	Test Result
[m]	[kJ]	[mm]	[m/s]	[–]
0,0	7	35	Low	Rupture
1,0	26	115	Medium	Rupture
	21	96	Medium	Stable
	27	77	Medium	Rupture
1,4	42	171	High	Stable
	29	113	High	Stable
	33	128	High	Stable

Solid Bar – Paddle Bolt

Introduction

The paddle bolt is designed for ground support conditions where a standard rebar is too rigid. Due to its increased energy-absorbing capacities for seismically active mines, this bolt system has provided proven support success.

Usage of high-strength low alloy (HSLS) steel allows an increased bolt capacity, maximum elongation properties allow absorption of a large portion of energy. One or two smooth sections of round rebar between paddle anchor zones ensure a controlled elongation and ground interaction. By default, the end anchor has 3 - 4 deformations and the collar anchor has 6 deformations.

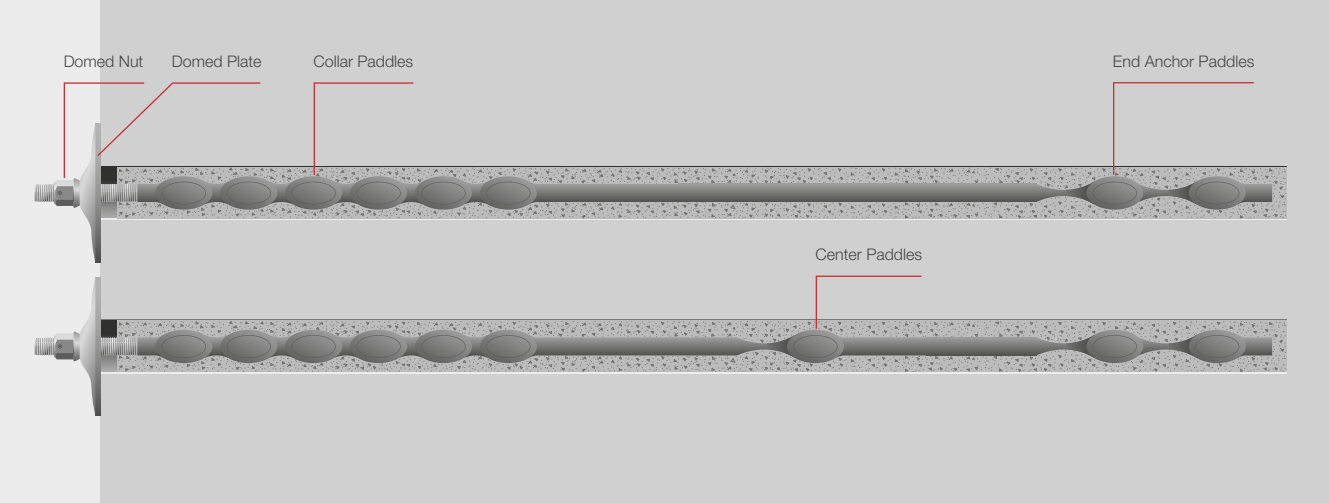
Main Advantages

- Proven system in underground mining
- Paddles in the area of the threaded bolt head prevent bolt failures in this section
- Enhanced resin cartridge mixing effect due to paddles in the up hole end
- Standardized mechanized installation with bolting rigs
- Proven performance by extensive testing: CANMET (CA) on the Canadian product version

System Description

- Smooth high-strength rebar with optional V-cut
- Customized paddles along the bolt length
- Central de-bonded smooth bar section (variable length)
- Bolt with additional center paddles available upon request
- Domed shear pin nut
- Fully grouted with FASLOC® resin cartridges or cementitious grout

System Components



Specifications (EMEA)

Characteristics	Unit	V20
Nominal diameter	[mm]	20
Nominal weight	[kg/m]	2,5
Nominal cross-section	[mm²]	314
Elongation A_5 1)	[%]	17 (24)
Yield load tendon 1)	[kN]	151 (165)
Ultimate load tendon 1)	[kN]	201 (237)
Yield load bolt head 1)	[kN]	133 (160)
Ultimate load bolt head 1)	[kN]	185 (213)

1) Nominal values, typical ones are indicated in brackets.
Further information can be found in local technical product brochures.

Dynamic Drop Test Results

CANMET

Section	Impact Energy
[–]	[kJ]
Split tube	> 33
Threaded bolt head	> 26

Dynamic Hollow Bar

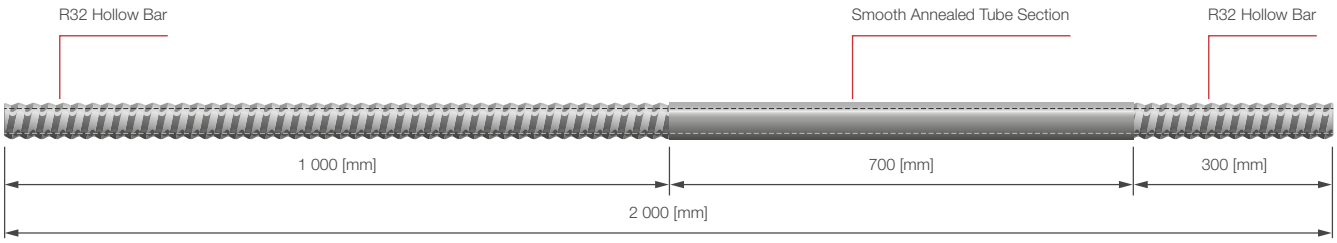
Main Advantages

- Proven system solution based on the DSI Hollow Bar System
- Installation both self-drilling and into pre-drilled boreholes

System Description

- Standard R32 hollow bar end sections
- Smooth seamless ductile annealed tube
- Optional extension with standard R32 couplings
- Bonding with cementitious grout or DSI Inject Systems

System Components



Specifications

Characteristics	Unit	R32-V20
Nominal diameter	[mm] / [in]	R32 / 1,25
Nominal weight	[kg/m] / [lb/ft]	3,0 / 2,0
Nominal cross-section	[mm²] / [in²]	380 / 0,59
Elongation hollow bar A_5	[%]	10
Elongation annealed section A_5	[%]	20
Yield load hollow bar	[kN] / [kip]	250 / 56,2
Ultimate load hollow bar	[kN] / [kip]	320 / 71,9
Yield load annealed section	[kN] / [kip]	220 / 49,5
Ultimate load annealed section	[kN] / [kip]	270 / 60,7

Friction Type – POWER SET

Introduction

The POWER SET self-drilling (S-D) friction bolt is a self-drilling ground control element used for underground applications. In addition, the POWER SET bolt system is deployed for rock fall and rock slide protection.

This patented one-step POWER SET bolt system stands for a safe and easy installation as well as immediate load-bearing capacity after installation. Another feature is the flexibility of the POWER SET regarding changing ground conditions.

Optional installation of an expansion element features additional mechanical anchorage up to the ultimate load of the friction bolt tube. A specially developed bolt magazine for six bolts per installation sequence allows a safe and state-of-the-art bolt installation.

Main Advantages

- Simultaneous drilling and installation
- Installation using standard drilling machinery
- Immediate load-bearing capacity after installation
- Direct load transfer over the entire bolt length
- Ability to maintain load-bearing capacity even when undergoing large deformations
- High shear strength
- Safe, easy, and fast installation procedure
- Trouble-free application under unstable borehole conditions
- No additional building materials such as grout, chemicals, or water required
- Ergonomic and safety-related advantages for the workforce

System Description

- Improved self-drilling friction bolt
- Frictional load transfer between bolt and borehole
- Application for bolting in remote areas or in case of unstable ground conditions
- Installation with standard rotary-percussive rock drilling equipment: controlled transfer of impact energy onto the friction bolt
- Optional installation of an expansion element: increase of the load-bearing capacity up to the ultimate load of the friction bolt tube
- Sacrificial corrosion protection for extended working life by increased friction bolt wall thickness
- Non-sensitive to nearby blasting works

System Components

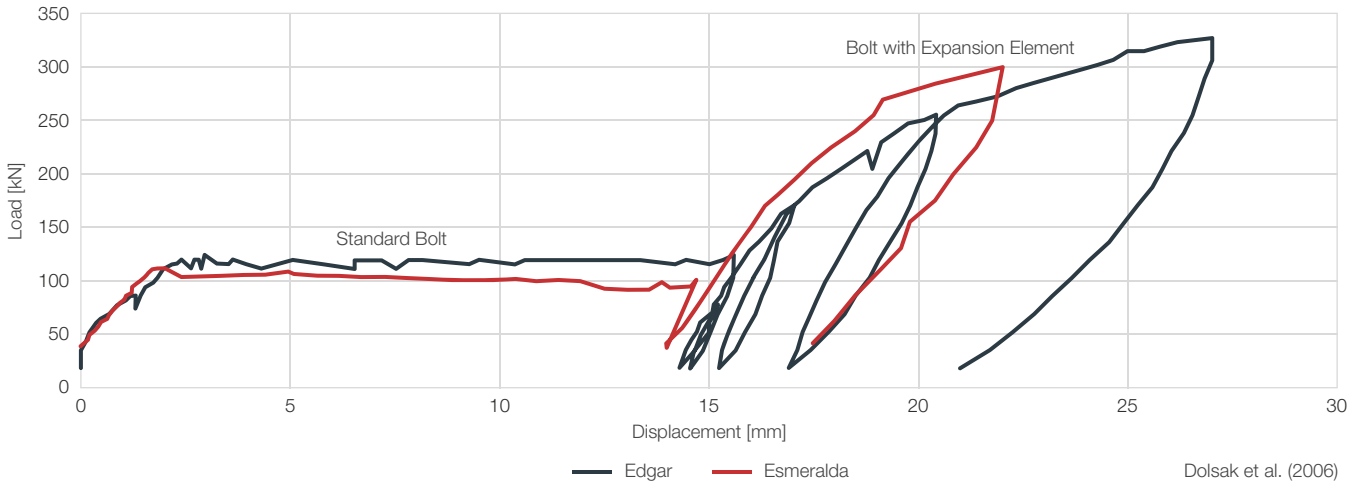
- POWER SET drill bit
  - Single-use drill bit available in different designs and dimensions, depending on ground conditions
- POWER SET drill rod
  - High-performance drill steel for optimum service life
- POWER SET adapter
  - Controlled transfer of the impact energy onto the friction bolt
- Domed plate
  - Different designs and dimensions available upon request
- POWER SET friction bolt
  - Slotted tube with bolt head and tapered end

Specifications

Characteristic Value / Type [1]	Unit	Type 1	Type 2
External diameter	[mm]	50	50
	[in]	2,0	2,0
Wall thickness	[mm]	3,75	5,0
	[in]	0,15	0,20
Nominal cross-section [2]	[mm²]	470	600
	[in²]	0,73	0,93
Ultimate load [3]	[kN]	330	300
	[kip]	74	67
Ultimate strength	[N/mm²]	700	500
	[ksi]	102	73
Guiding value shear force [4]	[kN]	370 - 470	360 - 420
	[kip]	83 - 106	81 - 94
Delivery lengths [5]	[m]	1,0 - 4,0	
	[ft]	3,3 - 13,1	

1) Note: all values are subject to change. 2) Rounded. 3) Calculated from the characteristic load value and nominal cross-section, rounded.
4) In-situ value for installed bolts. 5) Customized lengths are available upon request.

In-Situ Pull Test Results



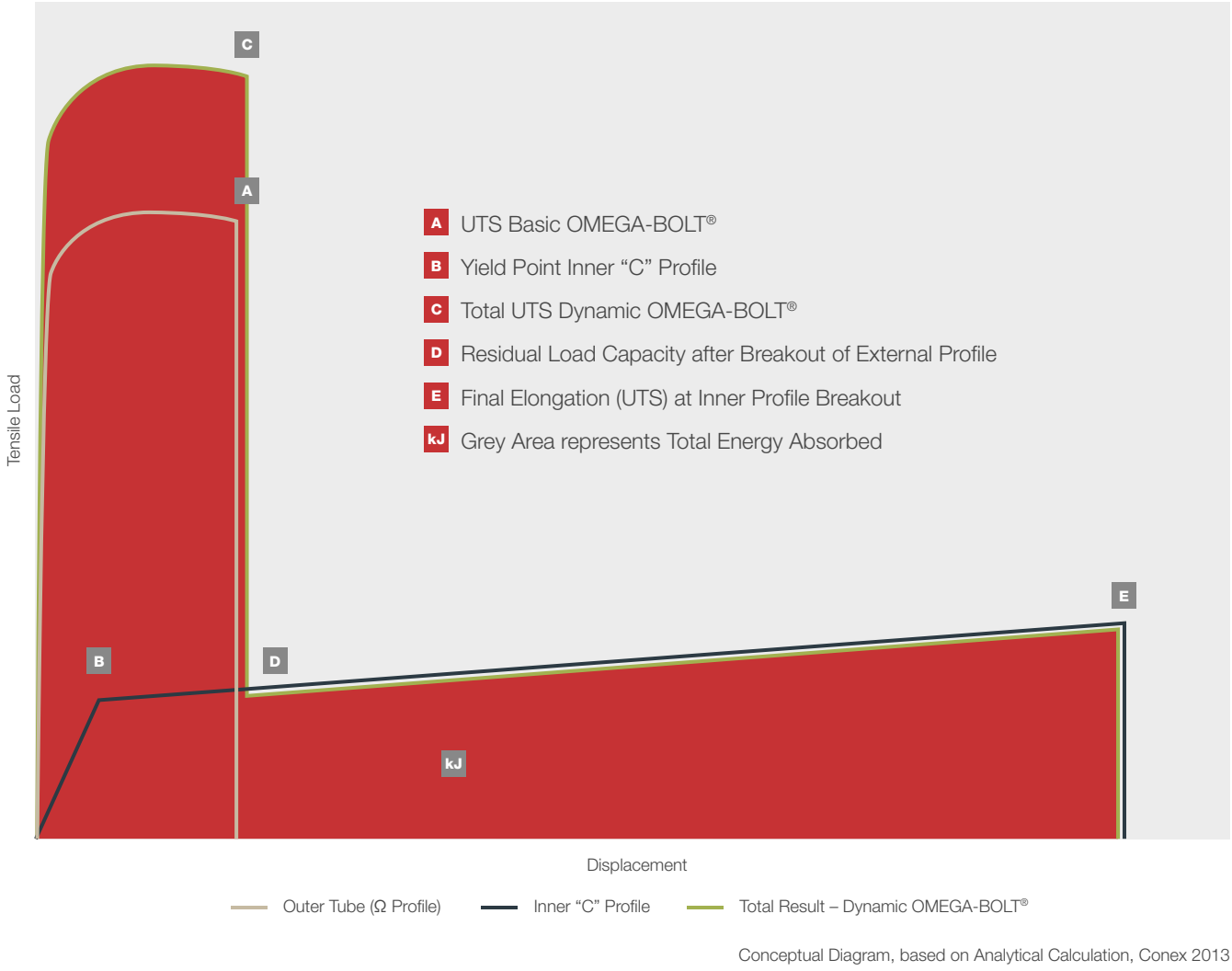
Dolsak et al. (2006)

Friction Type – Dynamic OMEGA-BOLT®

Introduction

The dynamic OMEGA-BOLT® is an advancement of the successful OMEGA-BOLT® expandable friction bolt system. It features an additional steel element which is placed inside the omega-shaped profile and welded onto the upper and lower bushings, which increases the static load-bearing capacity as well as allows to absorb additional energy in case of seismic events.

Based on the OMEGA-BOLT® EFB-160, the patented dynamic OMEGA-BOLT® is able to absorb 35 [kJ] of impact energy, while retaining a residual load-bearing capacity in the range of 70 [kN] (15,7 [kip]).



Conceptual Diagram, based on Analytical Calculation, Conex 2013

System Components

Specifications

Characteristics	Unit	Type 35
External diameter Ω profile	[mm] / [in]	36 / 1,42
Nominal weight	[kg/m] / [lb/ft]	3,75 / 2,52
Nominal cross-section [1]	[mm²] / [in²]	480 / 0,74
Elongation A_5 [2]	[%]	10 (15)
Ultimate load [1]	[kN] / [kip]	240 / 54
Shear load [3]	[kN] / [kip]	> 200 / > 45
Energy absorption [4]	[kJ]	35
Plate displacement [4]	[mm] / [in]	350 / 13,8
Required borehole diameter	[mm] / [in]	45 - 48 / 1,8 - 1,9

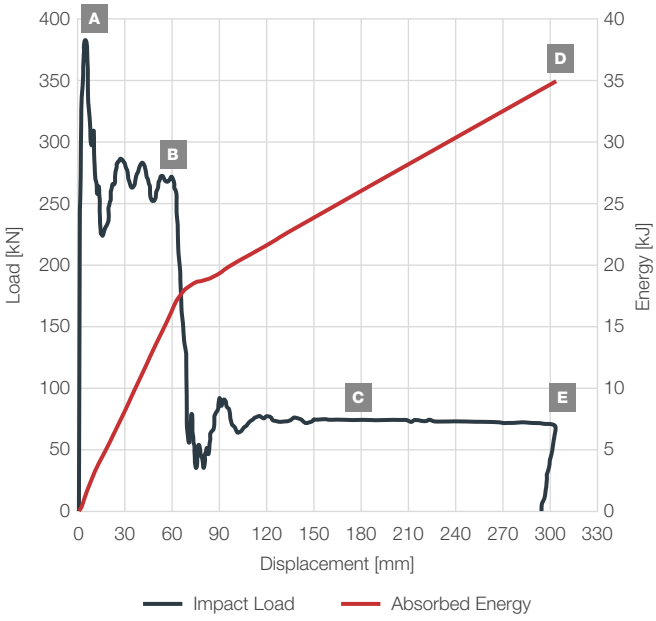
1) Ω profile and inside steel element.

2) Nominal values, typical ones are indicated in brackets.

3) SINTEF (NO) laboratory tests, 2014.

4) CANMET (CA) laboratory tests, split-tube configuration (one drop, bolt length 2,4 [m] (8 [ft])).

CANMET Dynamic Drop Test Results



Specimen MNS-7 Drop 1

Mass = 2 006 [kg]; Height = 1,5 [m]

Energy = 29,5 [kJ]; Velocity = 5,42 [m/s]

Peak Energy: 35,0 [kJ]

- **A** External Profile absorbing first Impact Energy
- **B** External Profile Breaking Out
- **C** Internal Profile absorbs further Energy (at Lower Load and Higher Deformation)
- **D** Peak Energy Absorption
- **E** Ultimate Breakdown

Drop No.	Input Energy	Top Displacement	Plate Displacement	Steel Elongation	Impact Peak Load	Absorbed Energy
[–]	[kJ]	[mm]	[mm]	[% of Strain]	[kN]	[kJ]
MNS-5						
1	29,52	5	388	16,1	369,48	37,09
2	19,68	Failed	17	0,7	166,15	0,84
MNS-6						
1	29,52	0	351	14,5	368,9	34,67
MNS-7						
1	29,52	0	294	12,2	216,18	34,89
2	19,68	–	1	4,16	53,69	N/A

Combination Type

Combination Rebar Bolts

Introduction

A solid rebar combination bolt offers the combined advantages of an immediate mechanical point anchorage and subsequently a fully grouted bolt. A two-step installation procedure allows fast installation and immediate anchorage; separate and independent grouting provides flexibility in terms of working cycles.

Due to the controlled grouting procedure and different bar coatings available, the solid rebar combination bolt is a reliable ground control system for underground applications. The working ability of the solid rebar combination bolt has been proven throughout various underground projects; the system has become a standard in today's state-of-the-art ground control procedures.

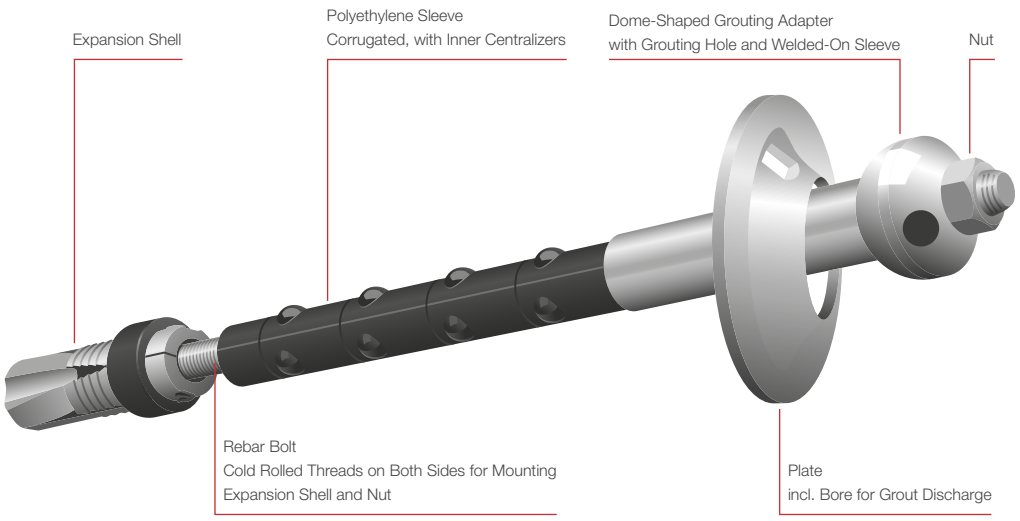
Main Advantages

- Efficient, practically proven, and reliable rock reinforcement system
- Combination of an immediate mechanical point anchorage and a fully grouted bolt
- Immediate load-bearing capacity of the mechanical anchor after installation
- Fast installation and flexible post-grouting behind the working face
- Double corrosion protection due to a polyethylene sleeve and grout coverage
- Easy adjustment of the corrosion protection level to customer demands
- Semi-mechanized or manual installation procedure

System Description

- Combination bolt
- Immediate mechanical point anchorage by activation of an expansion shell
- Pre-tensionable
- Post-grouting assembly features double corrosion protection
- Temporary or permanent application
- Suited for both manual and mechanized installation

System Components



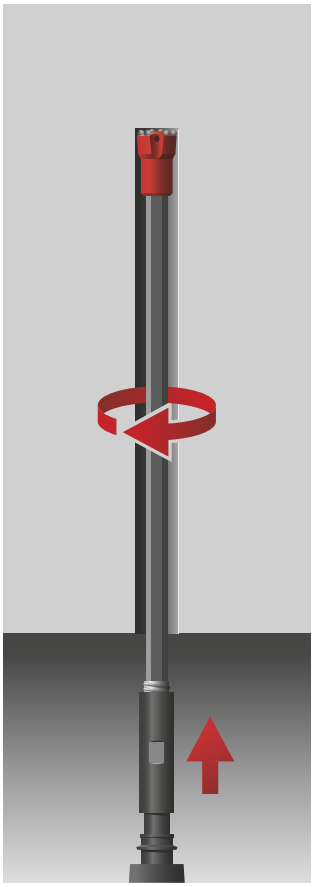
Specifications (EMEA)

Characteristic Value / Type		Unit	CT-M20	CT-M22	CT-M33
Rebar diameter		[mm]	20	21,7	32
		[in]	0,8	0,9	1,3
Thread designation		[mm]	M20	M22	M33
Mechanical anchor	Yield load [1]	[kN]	123	168	302
		[kip]	28	38	68
	Ultimate load [2]	[kN]	147	211	342
		[kip]	33	47	77
Grouted combination bolt	Yield load [1]	[kN]	157	226	383
		[kip]	35	51	86
	Ultimate load [2]	[kN]	188	282	440
		[kip]	42	63	99
Borehole diameter range		[mm]	45 - 52	45 - 48	63 - 67
		[in]	1,8 - 2,0	1,8 - 1,9	2,5 - 2,6

1) Calculated value with a safety factor of 1,15 against the yield strength (thread cross-section).

2) Calculated value with a safety factor of 1,05 against the ultimate strength (rebar cross-section).

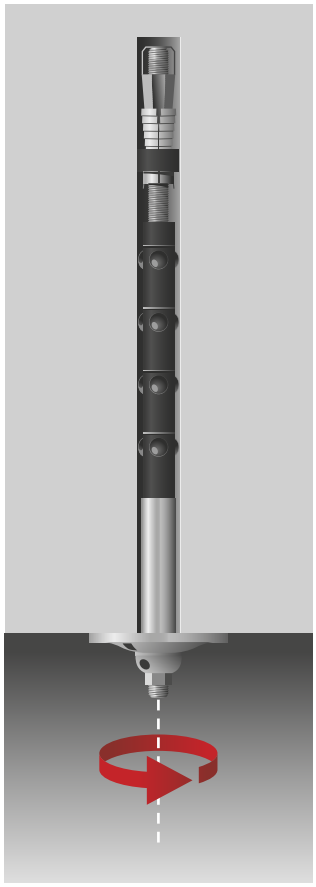
Installation Procedure



Borehole Drilling

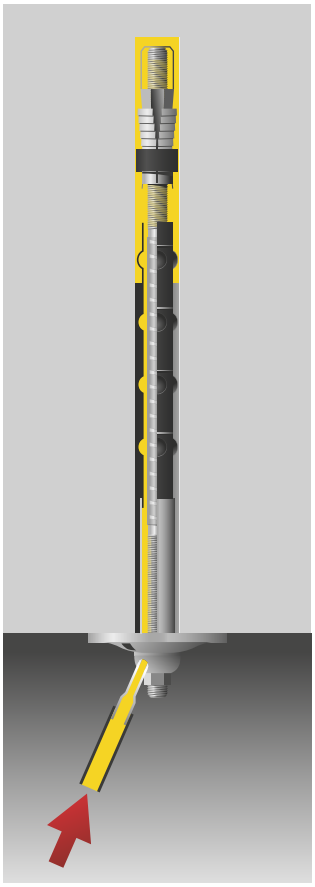
- Drilling of a borehole:
  Ø 44 - 51 [mm] (1,7 - 2,0 [in])
- Recommended borehole length: about 50 - 100 [mm] (2 - 4 [in]) longer than the bolt length

Note: larger (different) borehole diameters for CT26WR high-strength, combination cable, and combination GRP required



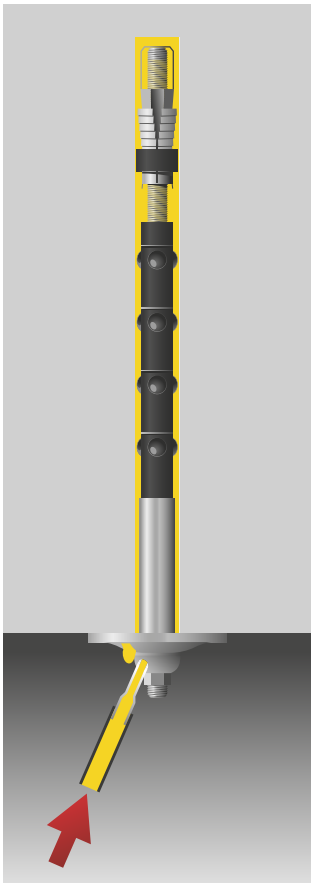
Bolt Installation

- Insertion of the assembled bolt into the pre-drilled borehole
- Pressing of the bolt plate firmly against the excavation surface
- Activation of the expansion anchor by pre-stressing of the anchor nut provides immediate mechanical point anchorage
- Typical torque manual installation:
  200 - 300 [Nm]
  (150 - 220 [lbf·ft])
- Typical torque mechanized installation: 500 [Nm]
  (370 [lbf·ft])
- In general, the expansion shell is tensioned up to max. 55 [kN] (12,5 [kip])
- In hard rock conditions and using a mechanized bolter, the expansion shell can be tensioned up to max. 100 [kN] (22,5 [kip])



De-Coupled Bolt Grouting

- Preparation of cement grout or bulk injection resin according to given specifications. For cement grout, the default W/C ratio is in the range of 0,35
- Connection of an injection adapter to the grouting bell
- Primary grout flow inside the sleeve towards the bolt's toe (expansion shell) – complete grout coverage of the rebar
- Secondary grout flow outside the sleeve until the grouting medium flows out at the bore for grout discharge at the hemispherical bolt plate
- Terminate grouting once the grout return is visible



Technical Features

- Active reinforcement by pre-stressing of the expansion shell anchor
- Allowance of a certain amount of elastic deformation of the rebar induced by displacements of the ground
- Flexible grouting behind the working face allows an optimum adaptation of the solid rebar combination bolt to given ground and operating conditions
- Optimum alignment and complete grout coverage of the bolt is ensured by the polyethylene sleeve

Unique Choice of the Corrosion Protection Level

- Protection of bolt components according to given levels of corrosive environments
- Bolts are available black, hot-dip galvanized, or with a special duplex coating (combination of hot-dip galvanizing, zinc phosphate, and powder coating).
  Special stainless steel versions are available upon request
- Indicated lifetimes for load-bearing components of the fully grouted solid rebar by accelerated corrosion tests from 50 years (black type) to 150 years (duplex coating)

Accessories

- Load indicators
- Pull testing equipment

Specifications (AU)

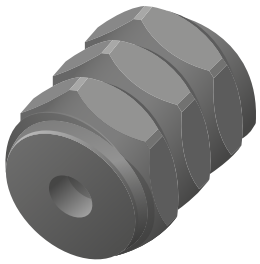
Characteristic Value / Type	Unit	CT400	CT26WR
Rebar core diameter	[mm]	21,7	–
Rebar major diameter	[mm]	23,2	30,5
Rebar cross-section	[mm²]	370	552
Unit weight	[kg/m]	2,9	4,76
Thread designation	[mm]	M24x3	WR26
Yield load	[kN]	220	524
Ultimate load [1)]	[kN]	310	579
Shear load [1)]	[kN]	205	382
Elongation A_{gt}	[%]	13	8
Borehole diameter range	[mm]	43 - 45	51 - 53

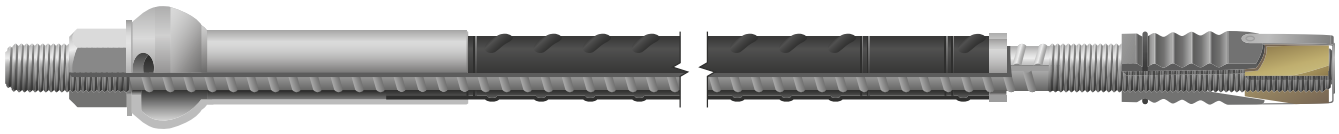
1) Calculated.

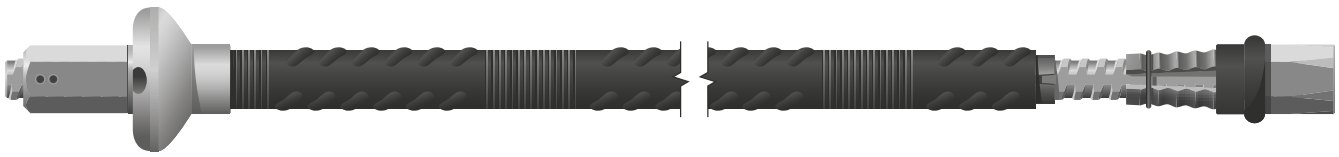
- Standard delivery lengths: 1,2 [m] to 9 [m]
- Special high-strength version type CT26WR available upon request
- Further information can be found in local technical product brochures

Optional Blind Nut End (AU)

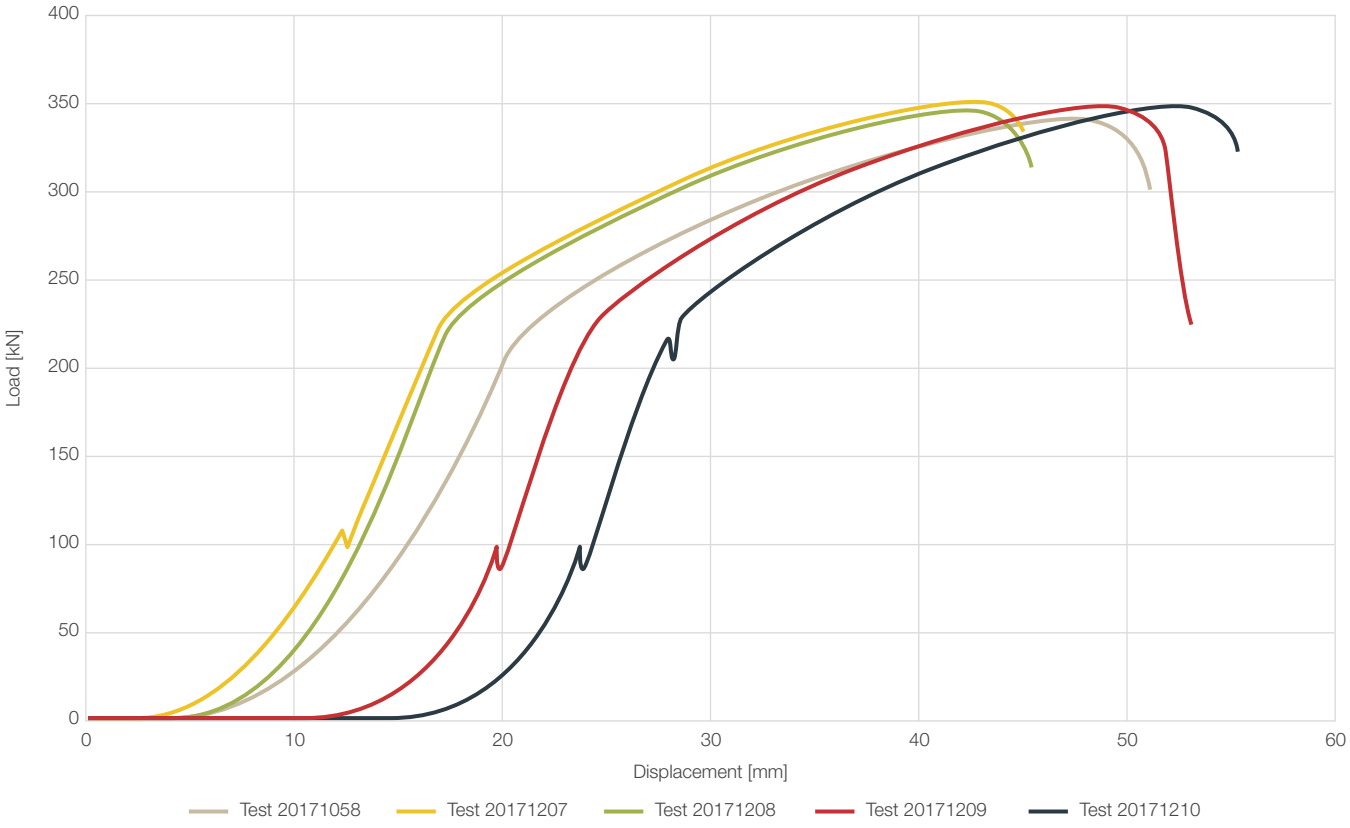
- No thread protruding below nut
- Reduced bolt tail protruding below roofline
- Existing bolts can be pull tested without need for special pull rings – the pull test coupler threads straight onto the exterior nut thread
- Standard hex nut size – standard bolt dollies
- Exterior thread exceeds 300 [kN]







Pull Test Results



Solid rebar combination bolt type CT400
Determined in the course of laboratory pull tests in model rock mass (concrete)

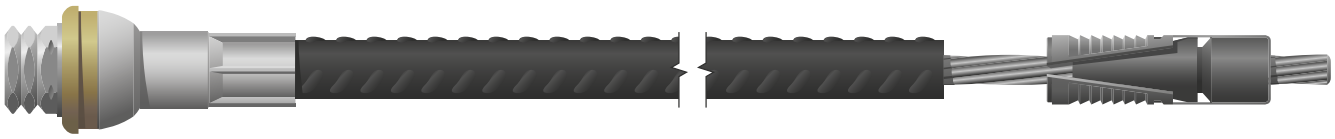
Combination Cable

- High load, flexible cable version of a tried and proven solid combination type bolt
- Facilitation of long bolts in low clearance areas
- Anchorage with a rotationally engaged (threaded) expansion shell
- Optional secondary tensioning with a hydraulic tensioner
- Spherical seat for grout cup alignment
- Stainless steel dome washer with plastic isolation system to separate black and stainless steel components
- Further information can be found in local technical product brochures

Specifications (AU)

Characteristic Value / Type	Unit	DCPCB1000
Cable (strand) diameter	[mm]	21,8
Unit weight	[kg/m]	2,7
Yield load [1)]	[kN]	495 / 525
Ultimate load [1)]	[kN]	573 / 595
Borehole diameter range	[mm]	63 - 65
HDPE sheathing	[mm]	Ø50 x 2,0

1) Minimum/typical.

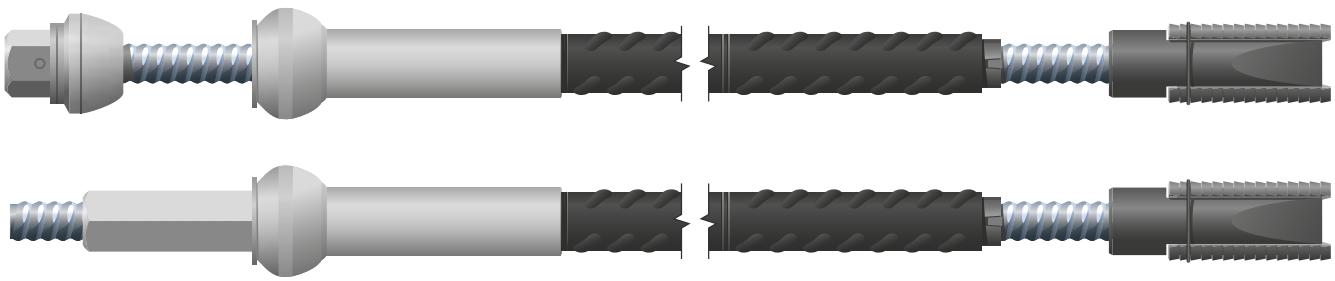


Combination GRP

- Fully threaded R25 glass-fibre reinforced plastic bar
- Further information can be found in local technical product brochures
- Cuttable fibreglass nut with breakout pin to show when enough torque/tension has been placed on nut (and bolt) after expansion shell has set
- Steel nut for higher design loads allows bolt to be pull tested via conventional methods connecting to the external thread on the nut

Specifications (AU)

Characteristic Value / Type	Unit	CTFB25
Bar core diameter	[mm]	21,7
Bar major diameter	[mm]	24,7
Bar cross-section	[mm^2]	346
Unit weight	[kg/m]	1,5
Thread designation	[mm]	R25
Yield strength	[N/mm^2]	460
Tensile strength	[N/mm^2]	1 000
Ultimate load	[kN]	350
Nominal shear load	[kN]	160
Ultimate elongation	[%]	2,5
Borehole diameter range	[mm]	43 - 45

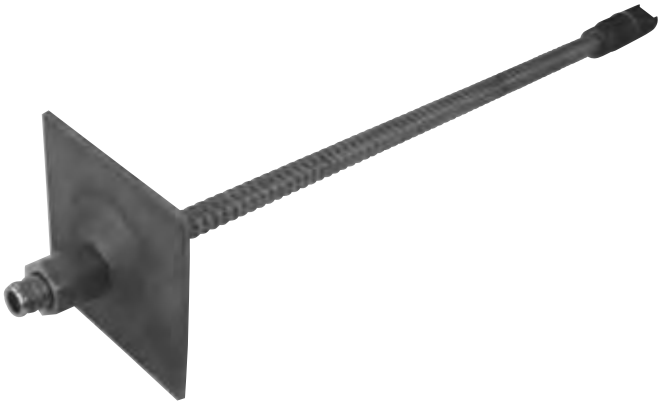


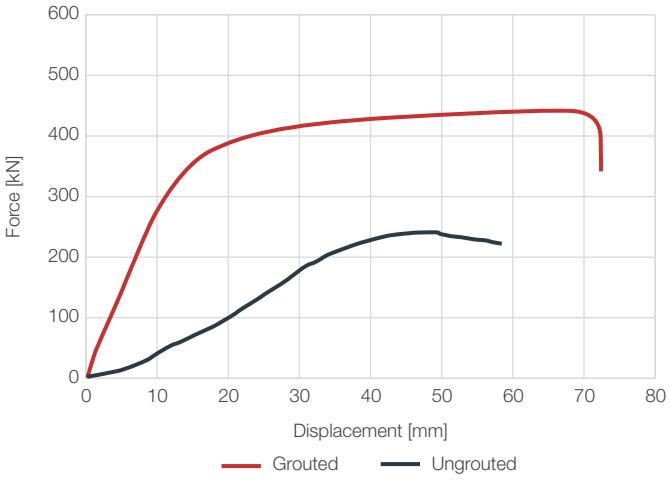
Combination Hollow Bar

Hollow Bar Expansion Shell Bolt

The hollow bar expansion shell bolt combines the benefits of a tensionable mechanical anchor featuring immediate support action and a fully grouted bolt. Based on the DSI Hollow Bar System, the tendon consists of a hollow bar.
Installation of the assembled bolt – including expansion shell, plate, and nut – is accomplished in a pre-drilled borehole. Optional post-grouting of the bolt is performed top down through the hollow bar.

Further information and specifications are included in the DSI Hollow Bar System catalogue section.





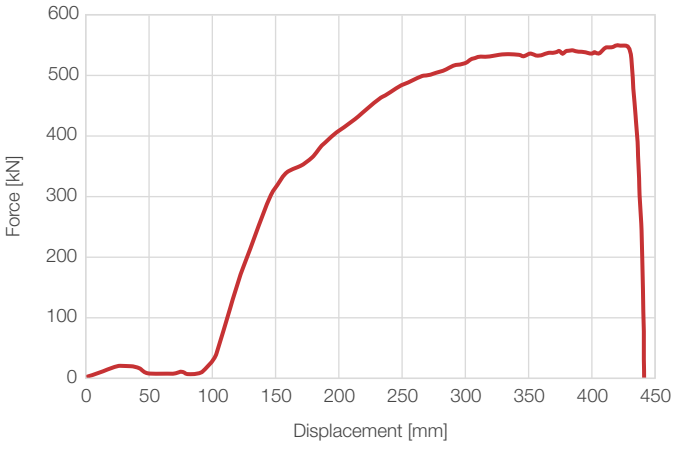
Expansion shell bolt type SK-R32-048, R32-400
Determined in the course of laboratory pull tests in model rock mass (concrete)

Hollow Bar S-D Expansion Bolt

The hollow bar S-D (self-drilling) expansion bolt combines a hollow bar system with an expansion shell element. The entire bolt assembly is installed self-drilling, activation of the expansion element is achieved by pulling the hammer back under hydraulic strokes. Tensioning of the bolt head and subsequent grouting are accomplished in separate working steps.

This innovative system solution is successfully used for installing bolts in areas which are difficult to access and in ground conditions with unstable boreholes. An active pre-tensioning of the bolt combined with grouting through the hollow bar member enables this system to function as a combination bolt.

Further information and specifications are included in the DSI Hollow Bar System catalogue section.



S-D expansion bolt type R38-076, R38-550
Determined in the course of laboratory pull tests in model rock mass (concrete)

Bonding Agents

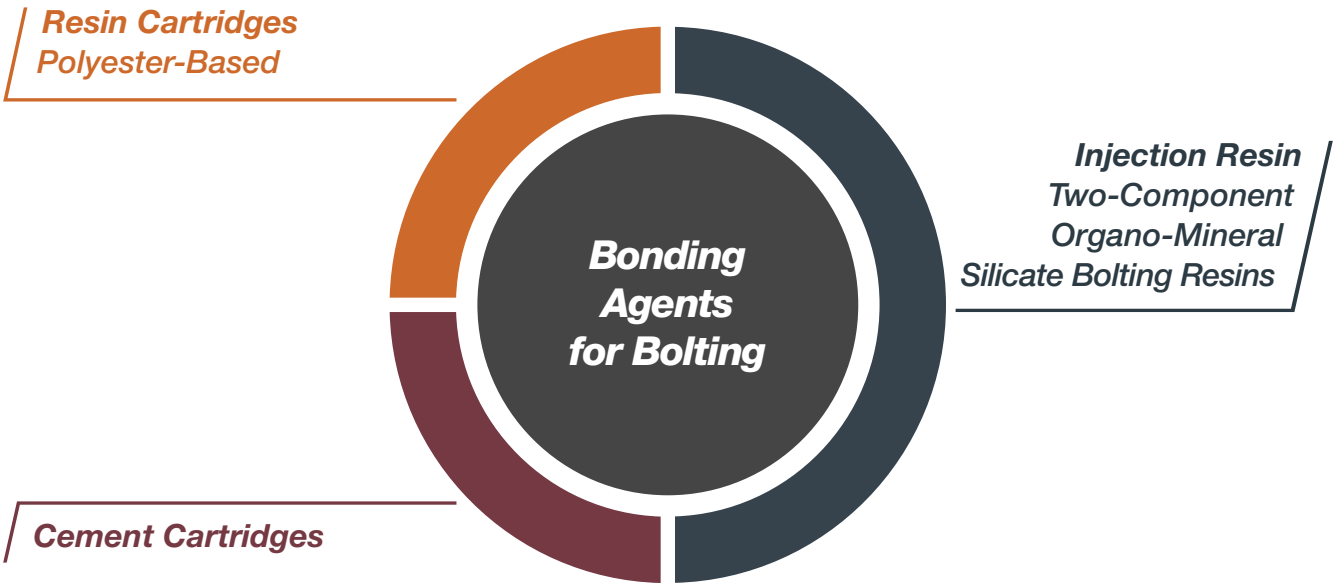
Introduction

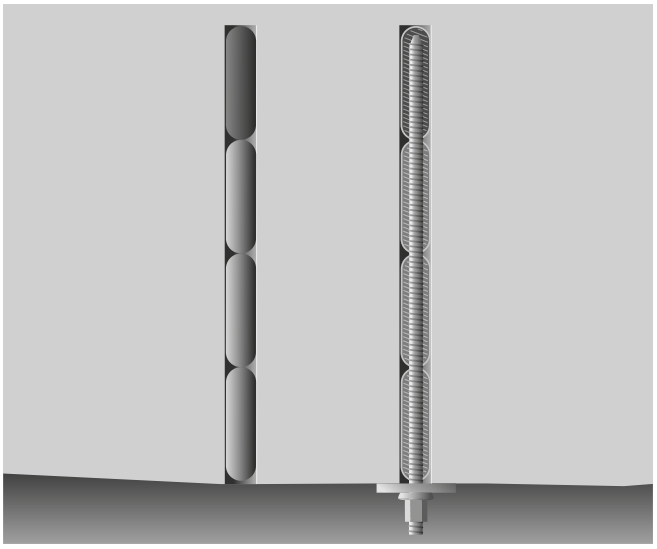
FASLOC® resin cartridges (also referred to as capsules) are used to bond bolts to the surrounding ground. Resin cartridge diameter and length must be optimized to bolt length as well as borehole and bolt diameter.
Bonding can either be accomplished using FASLOC® resin cartridges with the same setting (gel) time, or cartridges with different gel times allowing pre-tensioning of a bolt.

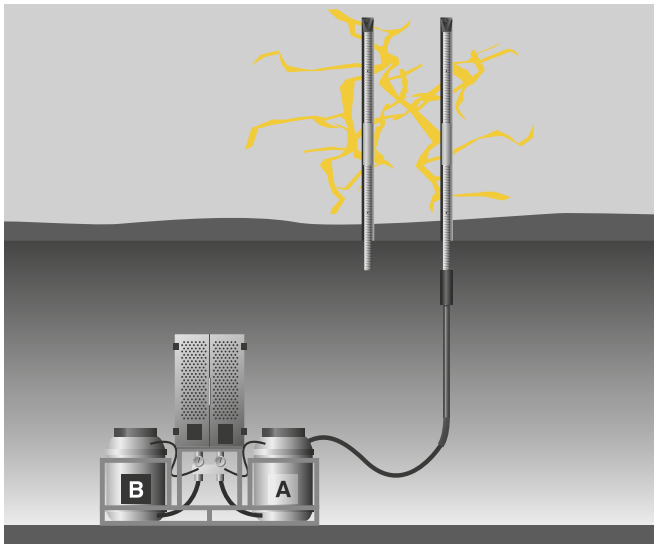
Mineral Bolt is a 2-component, high-strength organo-mineral silicate resin. This system is mainly used for bonding of anchors and bolts, further fields of application are ground stabilization, sealing against gas, and water stopping.

FASLOC® resin cartridges are manufactured at several global DSI Underground facilities. The global technical competence center for Mineral Bolt and DSI Inject Systems is based in Mikołów, Poland.

DSI Underground has long-term experience in design, manufacturing, and application of FASLOC® resin cartridges and DSI Inject Systems.







Resin Cartridges

System Description

Resin cartridges consist of two compartments: one containing resin mastic, the other one a catalyst. Separation of those two compartments is accomplished by a heat-sealed polyester film tube clipped at both ends. This chemical resistant film tube prevents migration between the resin mastic and the catalyst, and features an optimum shelf life. During the installation process, the film shreds quickly.

Resin cartridges are thixotropic and fast setting, allowing a low installation force and torque.

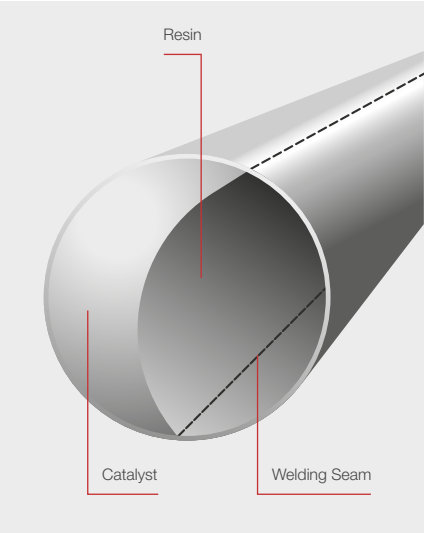
During application, the two components must be carefully mixed in a pre-drilled hole to guarantee optimum curing and bonding between the bolt and ground. A high catalyst/resin ratio and components with an optimized rheology enhance mixing efficiency and overall performance. Thanks to optimized ingredients and careful packaging, FASLOC® resin cartridges feature high durability – the components maintain unchanged properties over a long period of time.

Main Advantages

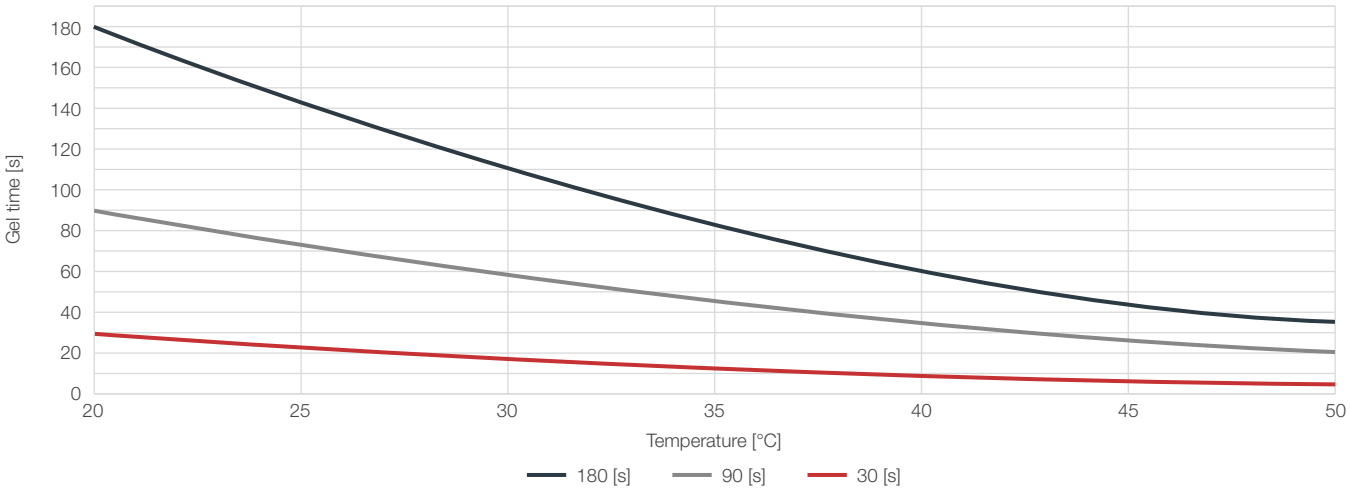
- Maximum bonding capacity due to optimized components
- Optimized installation times
- Durable and sound resin grouting
- Constant and customized gel times
- High catalyst/resin ratio
- Suitable for all ground types with stable boreholes
- Single speed and duo-speed cartridge types

Specifications

- Two-compartment cartridge – heat-sealed polyester film tube clipped at both ends
- Dark gray or colored mastic (resin)
- Light gray catalyst
- Nominal diameters for both SI Units and US Customary Units
- Cartridges are available in lengths from 200 [mm] to 2 000 [mm] (7,8 [in] to 78,7 [in])
- Deviating dimensions are available upon request
- Standard gel (setting) times: 30, 60, 90, 120, and 180 seconds
- Alternative gel times available upon request, range: 15 - 600 [s]
- Duo Speed cartridges contain two distinct resin gel times in the same convenient package
- Spin times depending on resin cartridge type
- Standard diameter ranges EMEA: 23 - 25 [mm], 27 - 30 [mm], and 32 - 40 [mm]
- Other diameters available upon request
- Gel times as indicated have been determined under laboratory conditions and at a temperature of 20 [°C]
- FASLOC® cartridges are non-hazardous materials in accordance with RID/ADR, IMDG, and ICAO/IATA transport regulations
- For complete technical and safety information, refer to local TDS (technical data sheets) and MSDS (material safety data sheets)



Gel Time vs. Temperature [1)]



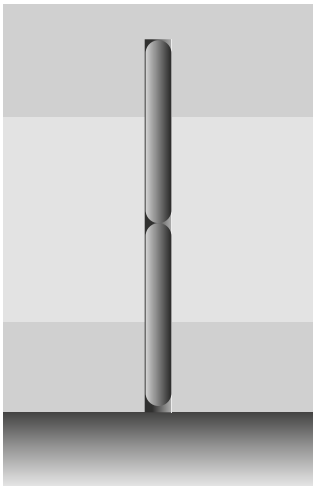
1) For other gel time vs. temperature curves refer to DSI Underground product data sheets.

Application Range DSI Solid Bar System

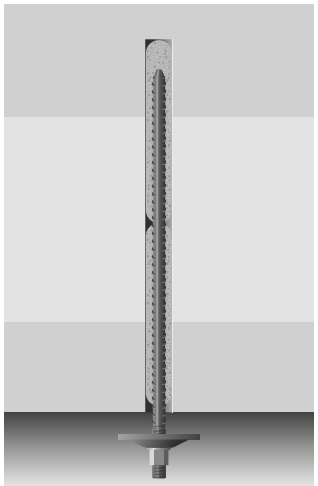
Borehole Diameter	[mm]	25	29	32	35	35	35	38	38	41	41	44	44	48	51
	[in]	1,0	1,125	1,25	1,375	1,375	1,375	1,5	1,5	1,625	1,625	1,75	1,75	1,875	2,0
Cartridge Diameter	**[mm]**	**23**	**25**	**28**	**28**	**30**	**32**	**32**	**35**	**32**	**35**	**40**	**40**	**40**	**40**
Bolt diameter [mm]	16,0	X													
	20,0	X	X	X											
	22,2		X	X		X	X								
	25,0			X	X	X	X	X	X		X				
	28,0				X	X	X	X	X	X	X	X	X		
	32,0									X	X	X	X	X	
	36,0											X	X	X	X
	40,0													X	X

Installation Procedure

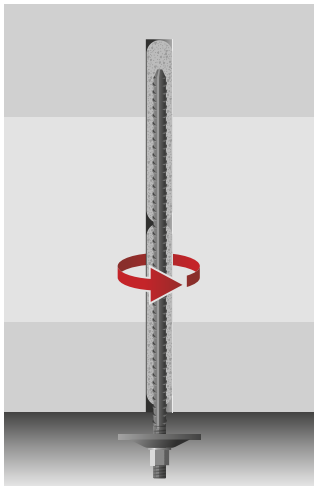
Installation Procedure Fully Grouted and Untensioned Bolts



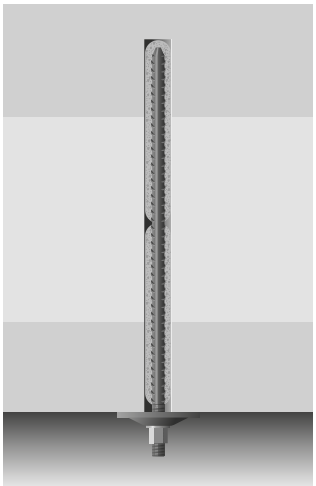
1. Insertion of required resin cartridges into a pre-drilled and cleaned borehole. Diameter, length, and quantity of cartridges depend on bolt length, bolt diameter, and bond length.



2. Insertion of the bolt into the hole to a point just below the excavation line. Slow rotation of the bolt during insertion is optional.



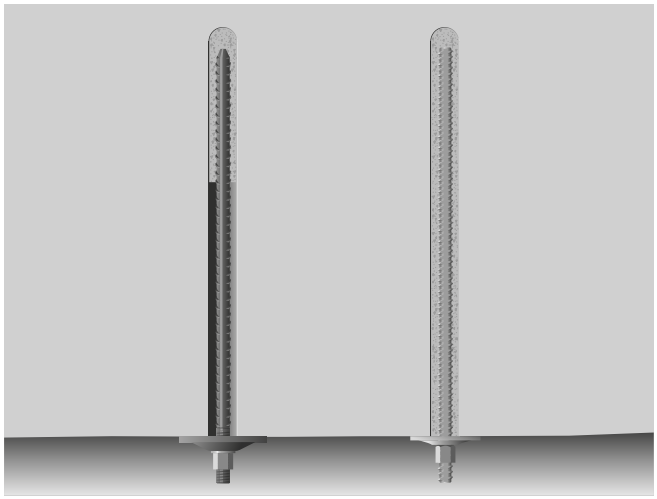
3. Bolt rotation. Note: follow rotation speed and spin time recommendations. 30 spins at minimum.



4. Push the bolt upward with the maximum thrust available from the machine and hold until the resin cartridges set.
   Do not rotate after step 3 – damage to partially gelled resin may result.

Installation Procedure Tensioned Bolts

1. Installation of one (point anchored) resin cartridge or a fast-setting and several slow-setting resin cartridges (fully grouted) into a pre-drilled and clean borehole
2. See step No. 2 above. By default, a shear-pin type bolt nut or similar is used.
3. See step No. 3 above.
4. Push the bolt upward with the maximum thrust available from the machine and hold until the fast setting resin cartridge sets. Then, rotate with a torque exceeding the breaking load of the shear pin nut and tension the bolt with the rated torque.



Tensioned Point Anchored *Tensioned Fully Grouted*

General Recommendations

- The relationship between borehole diameter, bolt diameter, as well as dimensions and the quantity of resin cartridges used per bolt is an influencing factor for the load-bearing capacity of the system
- Installation procedures should be followed carefully to ensure successful application of resin cartridges
- All instructions are general guidelines – on-site tests must be conducted to determine actual “mix” and “hold” times
- Additional technical and safety data is included in technial data sheets and material safety data sheets
- Resin usage charts and universal anchorage charts are available upon request

Quality Control

Performance Characteristics of a Resin Bolt Depend on Various Parameters such as

- Bolt (tendon) type
- Ratio bolt to borehole diameter
- Resin cartridge diameter and length(s)
- Borehole and encapsulation length
- Borehole excess (over-drilled) length

General Storage Recommendations

- Storage temperature must be lower than 30 [°C] (86 [°F]) at all times, the preferred storage temperature range is between 0 [°C] (32 [°F]) and 20 [°C] (68 [°F])
- Keep FASLOC® resin cartridges away from exposure to direct sunlight
- Store in dry environment, under cover, and with adequate ventilation
- Cold environment does not negatively influence the shelf life of FASLOC® resin cartridges, however a warm-up before use up to a temperature of approx. 15 [°C] (59 [°F]) is required
- Default shelf life when adhering to recommended storage conditions: nine months, reduced shelf life under adverse conditions
- Sound stock rotation (first in – first out) prevents waste

Handling and Occupational Safety

- FASLOC® resin cartridges are for industrial use only and are only intended for application in combination with bolts
- FASLOC® resin cartridges must neither be opened nor punctured
- Do not use ruptured or broken resin cartridges
- Safety glasses or eye shields are recommended during installation
- Physical contact with liquid cartridge components might cause slight irritations and must be prevented at all times
- In the unlikely event of eye contact, immediate and extensive flushing with clean water is recommended, followed by the consultation of a medical doctor

Mixing and Holding Times Depending on Rotational Speed [1)]

Gel Time	100 [RPM] [2)]		300 [RPM]		600 [RPM]		800 [RPM]	
[–]	Mix [s]	Hold [s]	Mix [s]	Hold [s]	Mix [s]	Hold [s]	Mix [s]	Hold [s]
15 [s]	NR		9 - 12	5 - 15	7 - 10	5 - 10	7 - 10	5 - 10
30 [s]	NR		10 - 20	5 - 25	10 - 20	5 - 15	10 - 15	5 - 15
60 [s]	20 - 40	10 - 40	20 - 30	10 - 30	20 - 30	10 - 30	20 - 30	10 - 30
90 [s]	20 - 40	10 - 40	20 - 30	10 - 30	20 - 30	10 - 30	20 - 30	10 - 30
Ultra slow	40 - 240	180 - 300	40 - 240	180 - 300	40 - 240	180 - 300	40 - 240	180 - 300
Duo speed	NR		20 - 30	10 - 30	20 - 30	10 - 30	20 - 30	10 - 15

1) Mixing and hold times are indications for default installation conditions (20 [°C] / 68 [°F]) and should be verified at the place of use.

2) NR … not recommended.

Insertion Tubes

- Bolting operations in high headings or caverns where a manual installation is not safe or practical
- Resin cartridges can be placed in the borehole from a remote location under supported ground
- Installation with a multiple-use plastic insertion tube and a threaded adapter connected to the drifter
- Retainer caps keep the resin cartridge in the borehole
- No requirement for loading baskets
- Tube adapter (T38)
- Resin insertion tube
- Retainer caps

Accessories

- Basket retainers
- Parachute retainers
- Top hat retainers
- Resin cartridges are provided with mounted retainers or alternatively with retainers in loose packs

Labeling and Packaging

Label Content

- Diameter
- Length
- Gel time
- Quantity per packing unit
- Weight packing unit
- Production and expiry date
- Batch number
- General HSE recommendations
- Installation procedure upon request
- Contact information

Packaging

- Default packing: 2-part cardboard boxes
- Standard aluminum clips, copper clips available upon request
- Customized packing upon request

Mineral Bolt – Silicate Injection Bolting Resins

Product Range

Product Designation	Product Name	Product Description
Organo-mineral silicate injection resin	Bolt MI	– Specifically designed thixotropic behaviour of the reacting mixture for mechanized bolting applications – Easy overhead installation of bolts – High ultimate strength and immediate load-bearing capacity after installation – Excellent adhesive and mechanical properties – Hydrophobic system, e .g. water does not affect or react with Mineral Bolt – Lower exothermic reaction temperature in comparison to PUR systems – Non-flammable – Absolutely environmentally safe when cured (inert system after reaction) – Approved application with the DSI Hollow Bar System and GRP hollow bars – Excellent corrosion protection
	Bolt F	– Fast setting
	Bolt M	– Medium setting
	Bolt S	– Slow setting
	Bolt US	– Ultra slow setting

Abbreviations

MI Mechanized Installation
F Fast
M Medium
S Slow
US Ultra Slow

Specifications

Characteristic Value [1]	Unit	Bolt MI
Mixing density [2]	[g/cm³] / [lb/yd³]	1,3 / 2,2
Foam factor [3]	[1]	1,0
Max. reaction temperature [3]	[°C] / [°F]	< 130 / < 166
Compressive strength [3], [4]	[MPa] / [ksi]	> 60 / > 8,7
Flexural strength [3], [4]	[MPa] / [ksi]	> 60 / > 8,7
Pull-out capacity after 3 minutes [5]	[kN] / [kip]	220 / 49,5
Pull-out capacity after 15 minutes [5]	[kN] / [kip]	310 / 69,7
Shore D Hardness [2], [6]	[1]	60

Product	Properties / Unit [1], [2]	
	Reaction Start Time	Tack Free Time
[–]	[s]	[s]
Bolt MI	5 - 35	50 - 70
Bolt F	45 - 60	70 - 90
Bolt M	105	180 - 360
Bolt S	180	480 - 600
Bolt US	285	600 - 720

1) The indicated values are laboratory values and may deviate on-site.
Store in original packaging and protected from moisture at temperatures between 5 [°C] and 30 [°C] (41 [°F] and 86 [°F]).
2) At 20 [°C] (68 [°F]).
3) At 25 [°C] (77 [°F]).
4) After 28 days.
5) According to DIN 21521 with a hollow bar bolt type R32-360 and Mineral Bolt F.
6) After 15 minutes and 60 minutes.
Further data and information can be found in technical data sheets from DSI Underground.

Installation Procedure

Cable Bolts

- Drilling of the borehole
  - According to given specifications with regards to diameter and length
- Insertion of the cable bolt into the borehole
  - With end holding device
  - Attached grout tube
  - Default bulbed version
- Optional sealing of the borehole collar
  - Spray foam or borehole plug
- Injection
  - Top down via the injection tube – connection of the injection tube to the static mixer via a quick coupling
- Tensioning
  - Fast curing time allows full cable tensioning within less than 15 minutes after installation

DSI Hollow Bar System or GRP Hollow Bars Type CH or CR

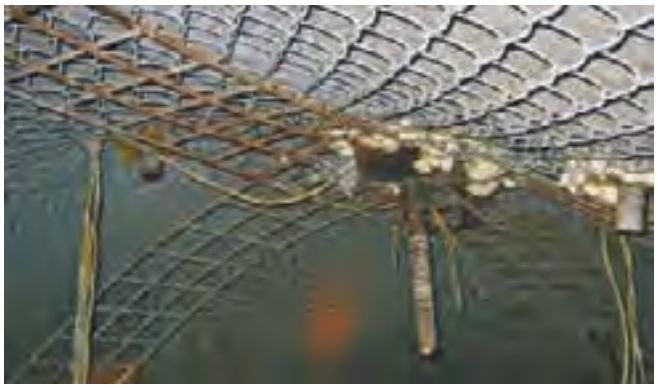
- Self-drilling installation or insertion into a pre-drilled borehole
  - Optional use of an end holding device
- Sealing of the borehole collar
  - Spray foam or borehole plug
- Injection
  - Resin flow upwards through the hollow bar, bottom down injection
- Tensioning
  - Fast curing time allows tensioning within less than 15 minutes after installation

Cable Bolt

DSI Hollow Bar System

Fish Hook

GRP Hollow Bar



Tests and Approvals

- Mineral Bolt fulfills German Mining approval standards (Bezirksregierung Arnsberg, Abteilung 6 Bergbau und Energie in NRW)
- Reaction temperature and flash point (DMT GmbH, Germany)
- Material consistency and self-ignition temperature (DMT GmbH, Germany)
- Compressive, bending, and tensile strength (Central Mining Institute, Poland)
- Conformity with NSW Australian Mining Standards (Mine Safety Technology Centre, Australia)
- Utility tests Mineral Bolt F and US in combination with DSI Hollow Bar System type R32-360 according to DIN 21521 (DMT GmbH, Germany)
- Mining hygiene testing and assessment of two-component systems for rock consolidation in accordance with §10 of the Mining Ordinance for Hard Coal Mines (BVOSt) and §18 of the Mining Ordinance for ore mines, rock salt mines, and for rock and earth operations (BVOESSE), in conjunction with DIN 22100 (Hygiene Institute Gelsenkirchen, Germany)

Injection Pumps

- Components A and B are processed with a 2-component high pressure pump and a static mixer – size M10
- Brace operated, pneumatically driven piston pump
- Independent intake of both components
- Robust design and little susceptibility
- Easy operation and handling
- Spare parts and starter sets available
- Technical data sheet and operation manual available upon request

Accessories

- Mixing tube and static mixers
- Connectors
  - Injection adapters
  - Special packer with integrated quick coupling for hollow bars
- Quick coupling and clamping tongs for cable bolts
- Further information regarding system accessories can be found in the catalogue section “Injection Chemicals”
- Separate DSI Underground catalogue for injection chemicals available upon request

Cement Cartridges

Introduction

Cement cartridges consist of a cementitious compound encased in a perforated package which, when immersed in water, will allow controlled wetting of contents, forming a thixotropic grout. The cartridge is then inserted into the hole and the deformed bolt or dowel is pushed in.

Main Advantages

- Convenient and easy-to-handle cartridge form
- Faster curing compared to standard cement grouts
- Controlled setting times and high-strength bonding
- Simple activation by immersion in water
- Thixotropic and non-shrinking performance
- No special grouting equipment required
- Non-toxic, non-combustible, and chloride free

Specifications [1)]

Characteristic Value / Type	Unit	CC-25	CC-28	CC-32	CC-35	CC-39
Outer diameter	[mm]	25	28	32	35	39
	[in]	1,0	1,1	1,3	1,4	1,5
Length	[mm]			600		
	[in]			23,6		
Soak time	[s]			60		

Characteristic Value / Type	Unit	2 Hours	4 Hours	1 Day	3 Days	7 Days
Compressive strength	[MPa]	12	14	21	35	43
	[psi]	1 740	2 030	3 050	5 080	6 240

1) Default shelf life: 1 year.

Installation Procedure

1. Remove required number of cartridges from the package.
2. Immerse cartridges in water until there are no signs of air release (bubbling) from the cartridge – do not leave in water for longer than 5 minutes.
3. The cement grout will begin to set in 20 minutes after initial water immersion; therefore the bolt must be installed within this time period. However, it is recommended that the wetted cartridges are used within 15 minutes to obtain optimum results.
4. Insert cartridges into a clean hole (tamp with a loading stick).
5. Insert the bolt, which will rupture the cartridges allowing the grout to fill the annular space between bolt and borehole. After 12 hours, the grout will typically withstand the full yield load of standard rebar bolts.

DSI MAI® Grout Mixing Pumps

Introduction

DSI MAI® grout mixing pumps have been developed for extremely challenging underground conditions. They have been used successfully around the world in Tunneling, mining, and civil engineering, for example for the shoring of slopes, hill sides, and building excavations.

DSI MAI® 400 NT is the most widely used grout mixing pump in underground construction. Further available types of grout mixing pumps are listed in the table below and are available upon request.

Main Advantages

- Tough design and easy handling
- Low empty weight
- Simple operation and maintenance due to modular design
- Short start-up and cleaning times
- High delivery rate at continuous pressure
- Variable discharge
- All-purpose equipment
- Highest process security
- Sustainable due to stainless steel components, galvanized frame, and wear resistant plastic components
- Comfortable cleaning
- Reverse drive possible

Fields of Application

Market Segments	Materials	Applications	DSI MAI® 440 GE	DSI MAI® 400 NT	DSI MAI® 400 EASY	DSI MAI® 400 HD	DSI MAI® 400 EX	DSI MAI® PICTOR
Heavy construction tunnels, dams, shafts	Cement, anchor mortars, premixed cement/sand/flyash mixes	Soil & rock	XXX	XXX	X	XXX	—	—
		Void filling	XXX	XXX	X	XXX	—	—
		Bolts	XXX	XXX	X	XXX	—	—
Mining	Cement, anchor mortars, premixed grouts	Bolts	—	—	—	XXX	XXX	—
		Spraying	—	—	—	—	XXX	—
Geotechnical	Cement, geothermal mortars, premixed grouts	Geothermal	XXX	XXX	X	XXX	—	—
		Well casings	XXX	XXX	XX	XXX	—	—
		Abandoned shafts/holes	XXX	XX	X	XX	—	—
Building construction	Cement, premixed grouts, plasters	Hollow filling-windows/doors	XXX	—	—	—	—	XX
		Precast	XXX	—	—	—	—	XXX
Restauration repair	Cement, premixed grouts, fireproofing, coating mortars, plasters/stuccos	Spraying	XXX	—	—	—	—	XXX
		Underfilling	—	—	—	—	—	XXX
		Waterproofing	—	—	—	—	—	XXX
		Repair mortar	XXX	—	—	—	—	X
		Toppings and final coatings	—	—	—	—	—	XXX

—: not suitable, X: limited suitability, XX: suitable, XXX: very suitable

System Components DSI MAI® 400 NT

- Pump unit
- Mixer
- Driving unit
- Protective grid with bag opener

Accessories

- Tools
- Water pump
- Automatic polarity control
- Cleaning equipment

- DSI MAI 440 GE
  - Compressor
  - Spray and filler guns
  - Cover hood for silo feeding
  - Dosing pump for additive dosage

- Pressure sensors for grouting
- Injection flow-pressure meter DSI MAI® LOG for data recording

Specifications

Characteristic Value / Type	Unit	DSI MAI® 400 EASY PLUS	DSI MAI® 400 NT	DSI MAI® 440 GE
Nominal power	[kW]	4,0	6,2	10,0
	[hp]	5,4	8,3	13,4
Gear motor	[rpm]	290	200	200
Delivery rate	[L/min]	16	8 - 34	5 - 54
	[gal/min]	4,2	2,1 - 9,0	1,3 - 14,3
Operating pressure	[bar]	25	40	40
	[psi]	360	580	580
Length	[mm]	1 616	1 755	2 010
	[in]	63,5	69,1	79,1
Width	[mm]	580	570	750
	[in]	23	22	30
Height	[mm]	900	960	1 030
	[in]	35	38	41
Filling height	[mm]	900	960	1 030
	[in]	35,4	38	41
Total weight	[kg]	136	230	360
	[lb]	300	507	794

Injection Flow-Pressure Meter DSI MAI® LOG

Introduction

The revolutionary injection flow-pressure meter DSI MAI® LOG permits an exact and comprehensible documentation of ground improvement as well as a control system of the specified injection termination criteria.

The appliance, designed for rough job site missions controls and supervises the use of injection-pumps in Tunneling, mining, and civil engineering. The flow rate and pressure measuring device is a separate, flexible module, which can be connected directly to an injection pump.

Main Advantages

- Tough design and easy handling
- Real time data recording of pressure, flow, and injection volume
- Automatic analysis of the working data
- Data transfer via compact-flash-card or USB
- Software for easy data transfer into a spreadsheet program
- Mountable on a tripod – for optimized handling on job sites
- Auto-power-off if defined pressure and/or volume is exceeded
- Pump control with DSI MAI® 400 GE and 400 NT
- Adjustments: operators can make adjustments themselves depending on the type of used material
- Measuring unit can be configured:
  - Pressure: 6 / 40 [bar] (90 / 580 [psi])
  - Flow rate: 4 / 12 [m³/h] (140 / 425 [ft³/h])

System Description

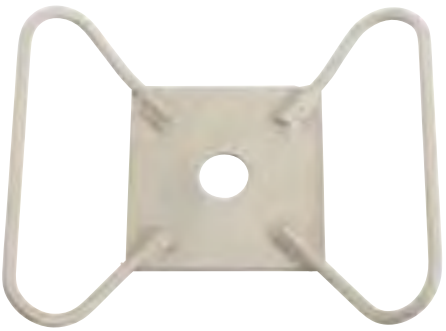
Flow rates and injection pressures are recorded separately for each injection borehole. The manipulation-proof digital data recording is operated via an user-friendly and simple touch-screen terminal. The easy handling and the integrated software, which allows the input of the working data into a spreadsheet calculation program, are a benefit for each job site.

The acquired data is shown in real time. Thanks to the DSI MAI® LOG data-import-software, all recorded data can easily be transported to a laptop or PC into a spreadsheet program. There, the data evaluation is shown in terms of a consolidated overview with graphics and tables.

Accessories

Plates

- Standard versions: domed or flat plate
  - Standard dimensions are included in DSI Underground's system approvals
  - Domed plate: length and width up to 250 [mm] (9 27/32 [in]) and wall thickness up to 20 [mm] (25/32 [in])
  - Flat plate: various dimensions available upon request
  - Custom-specific lug designs (dog ears) for domed plates
  - Plates can be made with round or long holes
- Steel grade
  - Europe: S235 or S355 according to EN 10025-2
  - North America: ASTM A 1011: grade 35 or higher
  - Other steel grades available upon request
  - Black, galvanized, or coated versions available
- Special plates
  - Light-weight butterfly plates for surface control
  - Surface control plates for friction bolts
  - Spider (shotcrete) plates for use in combination with bolts and shotcrete
  - Push-on mesh plates
  - Other plates are available upon request
- Further information can be found in local technical product brochures



Straps

OSRO Straps [1)]

Length		Width		Horizontal Bar Diameter		Strapping Bar Diameter	
[mm]	[in]	[mm]	[in]	[mm]	[in]	[mm]	[in]
1 000 - 6 000	39 - 236	250 - 1 000	10 - 39	6 - 10	0,25 - 0,40	5,5	0,2

W-Straps [1)]

Length		Width		Wall Thickness		Standard Hole Spacing	
[mm]	[in]	[mm]	[in]	[mm]	[in]	[mm]	[in]
1 000 - 3 000	39 - 118	220 - 500	9 - 20	1,5 - 6,0	0,05 - 0,25	500	20

1) Alternative dimensions available upon request, bore diameters are customized.

Pull Testing Equipment

Introduction

Pull testing equipment is required for non-destructive and destructive pull-out tests on anchors and bolts.

Pull-out tests on anchors and bolts are performed for supervision of the bolting quality. Depending on the type and design of the bolt in use, different testing equipment is utilized.

Adjusted to the operation purpose, modularly designed sets of different pull testing equipment can be adapted to the whole range of bolts provided by DSI Underground.

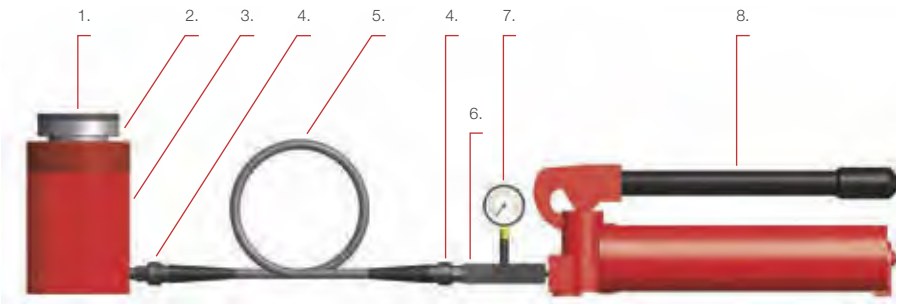
System Components

Pull testing equipment consists of a series of mechanic and hydraulic components and is designed for an ultimate test force of up to approx. 60 [t] (66 [ST]).

- Hydraulic components
  - Hollow plunger cylinder
  - Hydraulic hose
  - Electric pump or hand pump, with manometer
  - Manometers can be provided with a calibration certificate
- Supporting frame
  - Depending on test requirements and test forces, the frame is available either as a tripod or a tubular frame in different sizes
- Mechanical components
  - Intermediate disks
  - Angle compensation plates
  - Pull rods and pull couplings for bolts that are to be tested

Components

1. Bearing plate hollow plunger cylinder/nut
2. Thrust piece
3. Hydraulic hollow plunger cylinder, single acting
4. High-flow coupling
5. Hydraulic hose
6. Manometer piece
7. Manometer (incl. calibration certificate)
8. Hand pump or compact electric pump



Specifications

Anchor or Bolt Type	Hydraulic Cylinder [1]		Tripod or Bearing Cylinder [2]		Pull Adapter [3]
	Max. 320 [kN] (72 [kip])	Max. 640 [kN] (144 [kip])			
DSI Hollow Bar System	X	X	X	X	Coupling, hollow bar, and nut
DSI Solid Bar mechanical anchor	X		X		Coupling, rod, and nut
Mechanical rebar anchors	X		X		Pull adapter, washer, and nut
DSI Solid Bar System	X	X	X		Coupling, rod, and nut
SN-Bolts and resin bolts	X		X		Pull adapter, washer, and nut
Combination Bolts	X	X	X		Coupling, hollow bar, and nut
Solid rebar combination bolts	X		X		Pull adapter, washer, and nut
OMEGA-BOLT® expandable friction bolts	X		X		OMEGA-BOLT® pull head, washer, and nut
POWER SET self-drilling friction bolts	X			X	POWER SET pull testing equipment
Friction stabilizers	X		X	X	POWER SET pull testing equipment
Cable bolts	X	X	X	X	See catalogue section “Cable Bolt Tensioners”
GRP bolts	X		X	X	Coupling, hollow bar, and nut

1) Proof force range of 0 - 320 [kN] (0 - 72 [kip]): hollow plunger cylinder type RCH-302 / proof force range 0 - 640 [kN] (0 - 144 [kip]): hollow plunger cylinder type RCH-603.

2) Tripod or bearing cylinder according to hydraulic cylinder type.

3) Schematic display. Coupling, pull head, pull rod, washer, and nut are adapted to each anchor and bolt type.

Further References

- DSI Underground’s leaflets on pull tests
- System sketches of test assemblies
- Data sheets and operating procedures
- Pull tests must only be carried out in compliance with the present instructions and by skilled personnel
- DSI Underground has experienced technical personnel for planning, operation, and analysis of pull tests

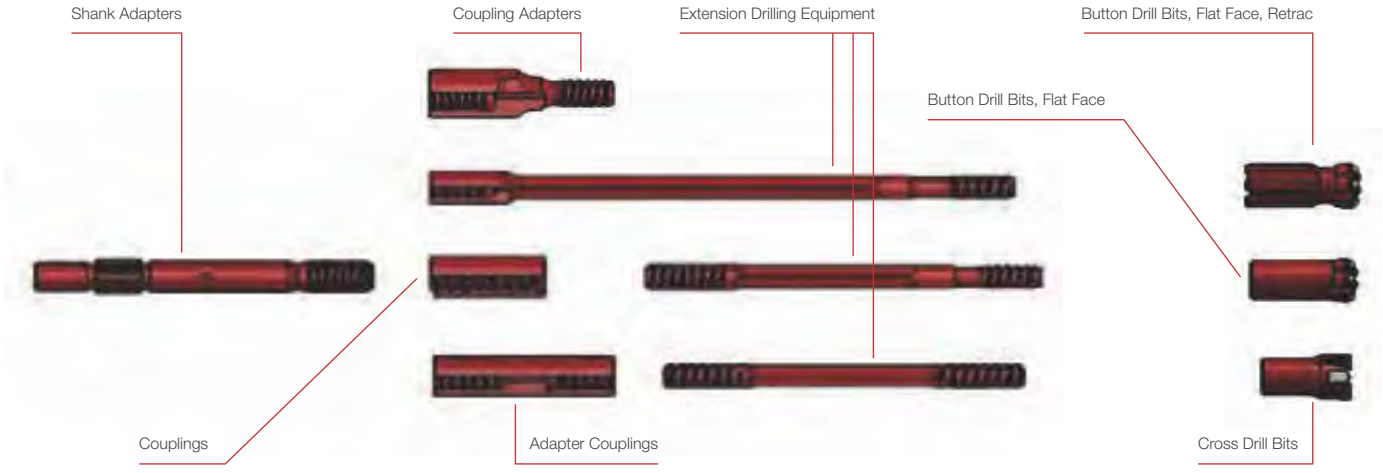
Rock Drilling Equipment

Fields of Application

- Blasthole drilling
- Production drilling
- Extension drilling
- Overburden drilling
- Pre-drilling

System Components

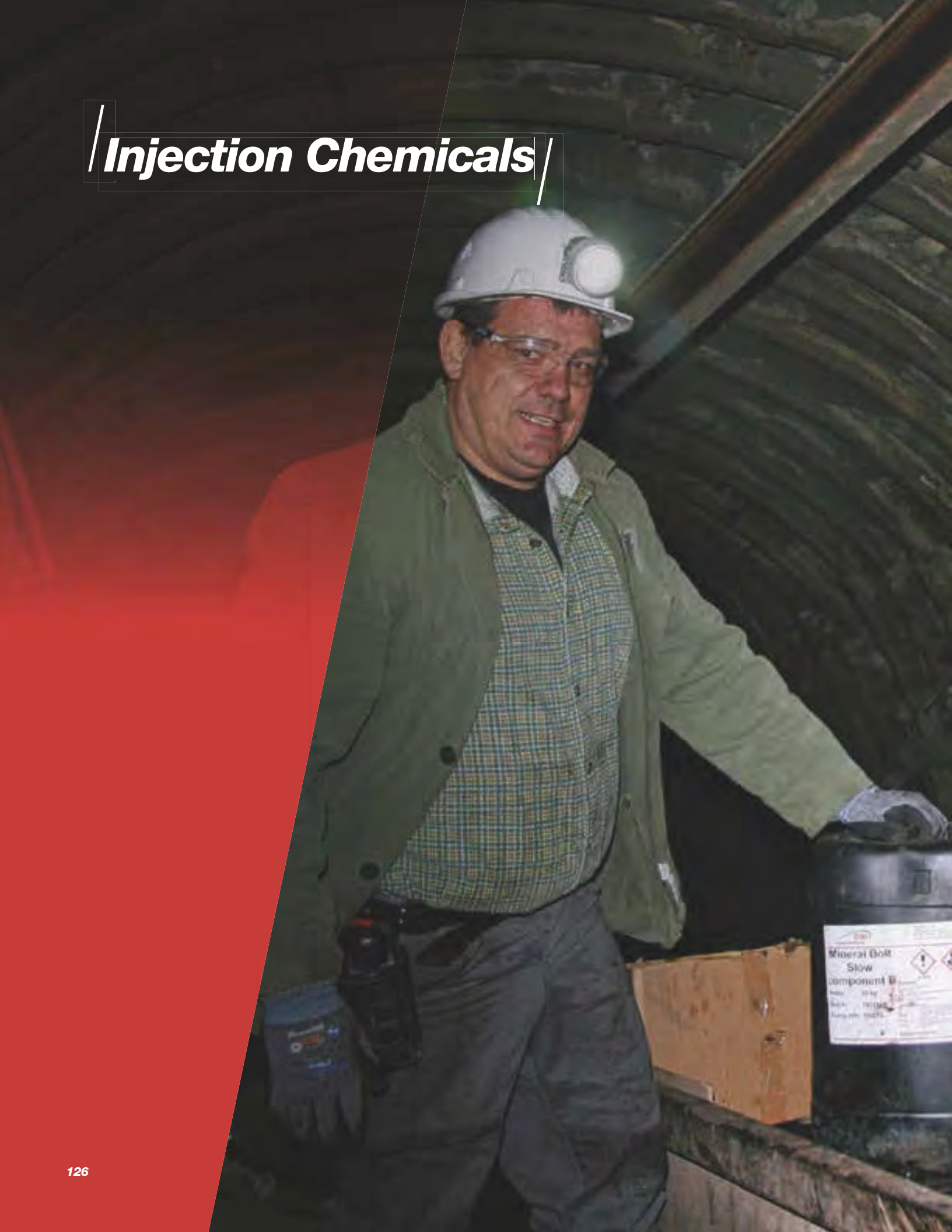
- Shank adapters
- Couplings
- Adapter couplings
- Extension drilling equipment
- Coupling adapters
- Drill bits
  - Drill bits in either flat face or retrac design
  - Cross drill bits
- Pre-drilling bits for the AT-SYSTEM
- Various adapters and driver tools for bolts
- Individual drill bits available upon request



Miscellaneous

- Mesh
  - Welded wire
  - Chain-link
  - Blank or galvanized
  - HEA mesh for rockburst prone ground conditions
  - PVC grids
  - Separate local technical data sheets available
- Load and torque indicators
  - Reliable indication for a correctly installed bolt
  - Assembly between nut and bolt plate
  - Available for different bolt types
- Centralizers
- Scaling bars
- Eye bolts and utility hangers
- Eye nuts and sill nuts
- Spacers
- Angle compensation disks
- Protective caps
- Driver tools, dollies, and spanners
- Drill rod wrenches
- Cable and bar truss systems
- Grouting and injection adapters
- Ventilation systems: regionally available
- Further information can be found in local technical product brochures

Injection Chemicals



Contents

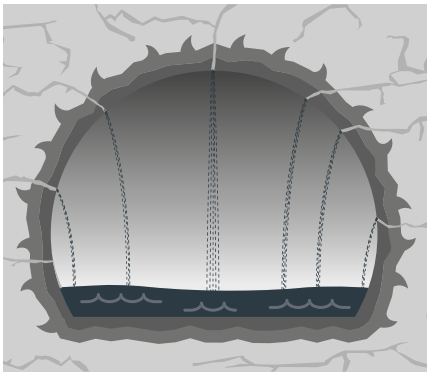
Introduction

The DSI Inject product line comprises injection resins used for underground and civil engineering applications. 2-component polyurethane systems (PUR) are the most versatile injection resin system and are mainly used for stopping water ingress and ground consolidation.

2-component silicate systems (SIL) have a broad application range with excellent bonding capabilities. Single-component resins (SCR) are widely used for smaller-scale repair works, and acrylic resins (ACR) have been successfully used for ground consolidation and grout curtain applications.

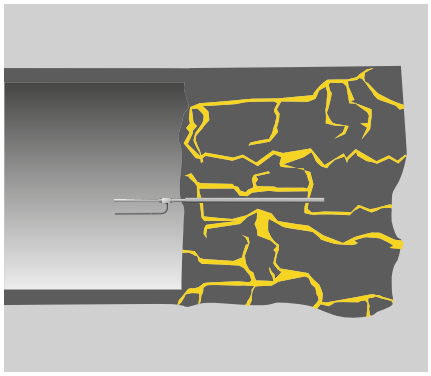
All DSI Inject Systems are processed with 2-component or 1-component high pressure pumps, tailored for each project and application. Mixed and cured DSI Inject Systems are ecologically approved, solid (CFC and halogen free), and suitable for application in ground water areas.

Fields of Application



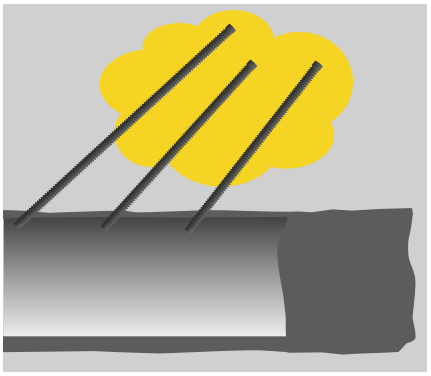
Sealing

- Water ingress
  - Temporary or permanent
  - Amount of water
- Pressing water
  - Temporary or permanent
  - Pressure range
  - Amount of water
- Leaking gas
  - Gas type
  - Amount of gas
  - Escape ways
- Product range
  - PUR fast-setting
  - PUR foam
  - SCR
  - SIL foam



Consolidation and Stabilization

- Consolidation
  - Geology
  - Required grade of improvement
- Stabilization
  - Geology
  - Temporary or permanent
- Product range
  - PUR med-slow setting
  - PUR foam
  - SCR
  - SIL
  - SIL foam
  - ACR



Filling

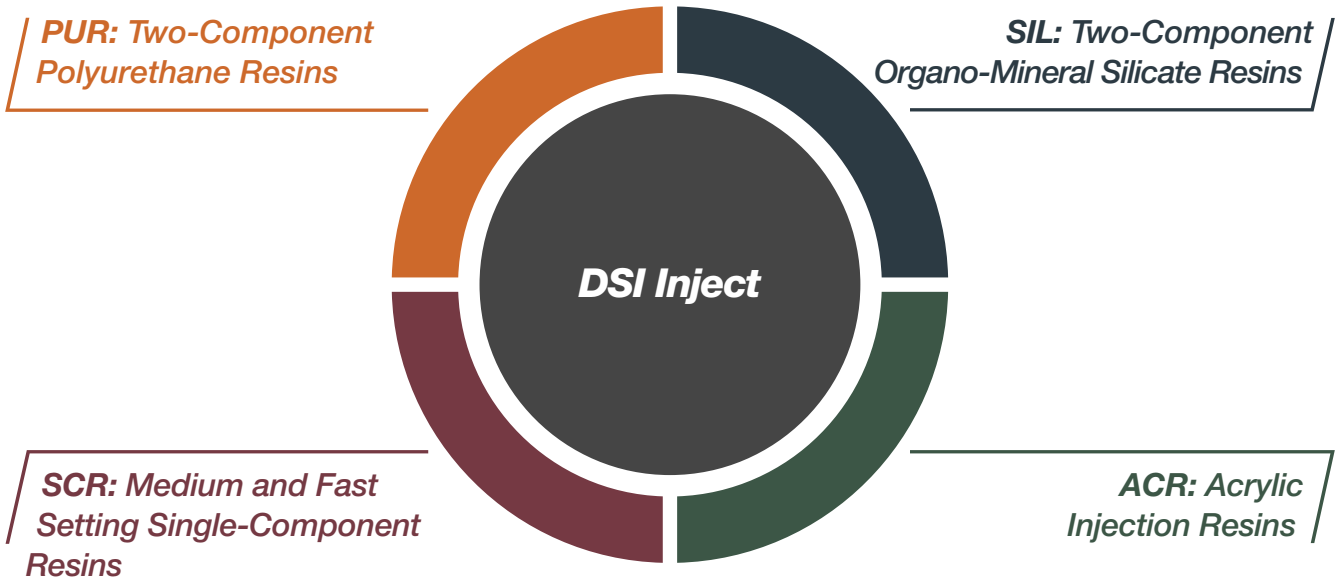
- Filling of cavities
  - Cavity size
  - Required grade of improvement
- Backfilling
  - Gap width
  - Presence of water
- Product range
  - SIL foam

Full Portfolio of Solutions

Type	Product Designation	Application							
		Water Ingress	High Pressure Water Ingress	Sealing (Gas & Water)	Ground Stabilization	Ground Consolidation	Cavity Filling	Backfilling	Bolt Bonding
Two-Component Resins									
PUR (2C)	Fast setting polyurethane resins	+++	+++	+	++	+	-----	-----	++
	Medium and slow setting polyurethane resins	-----	-----	++	+++	+++	-----	-----	+
	Fast setting polyurethane foam resins	+++	+++	+	++	-----	-----	-----	-----
SIL (2C)	Organo-mineral (silicate) resins	-----	-----	++	+++	+++	-----	-----	+
	Organo-mineral (silicate) bolting resins [1]	-----	-----	+	++	-----	-----	-----	+++
	Organo-mineral (silicate) foam resins	++	-----	+	+++	+++	+++	+++	-----
Single-Component Resins									
SCR (1C)	Fast and medium setting polyurethane resins	+	-----	+++	++	+	-----	-----	-----
	Slow setting polyurethane resins	-----	-----	+	++	++	-----	-----	-----
Acrylic Resins									
ACR	Acrylic resins	-----	-----	-----	+++	+++	-----	-----	-----
	Acrylic gel resins	-----	-----	+++	++	+	-----	-----	-----

1) See catalogue section “Mineral Bolt”.

“+” Recommended, “-” Not recommended.



Grouting Fundamentals

Step 1: Identify the Application

- Sealing
- Consolidation and stabilization
- Filling

Step 2: Determine the Grouting Material

Three Commonly used Types of Grouting Material

- Suspension
  - Water + cement (e.g. micro-cements, ultra-fine cements, etc.)
  - Water + cement + fillers (e.g. sand, fly ash, etc.)
- Solution
  - Chemicals diluted in water (e.g. water glass + hardeners)
  - Polyurethanes (e.g. 1C one component, 2C two components)
  - Acrylates
- Emulsion
  - Silicates

Limitations in the Application of Cementitious Grouts

- Dilution in general
- Partial penetration
- Large openings
- Permeability range below 10^{-6} [m/s]
- Low temperatures

Application Window for Injection Resins

Polymer resins must be used if at least one of the following criteria applies:

- Discontinuities
  - Large-size joints or caverns
- Permeability and hydraulic conductivity
  - Lugeon < 15 - 20
  - Permeability < 10^{-6} [m/s]
- Groundwater
  - Velocity > 20 [mm/s]
- Water and ground temperature
  - Below 3 - 5 [°C]

Step 3: Method Statement

- Qualified and experienced expert(s)
- Clear identification of the on-site situation
- Type of injection resin
- Material properties with reaction profile
- Application team
- Equipment

Step 4: Application and Verification

- Implementation according to the method statement
- Continuous data monitoring
- Attention to predefined stop criteria
- Qualitative and quantitative evaluation of injection results
- Determination of further steps, if required

Competence in Application

Permeability in Soil and Jointed Rock Mass

Method Statement

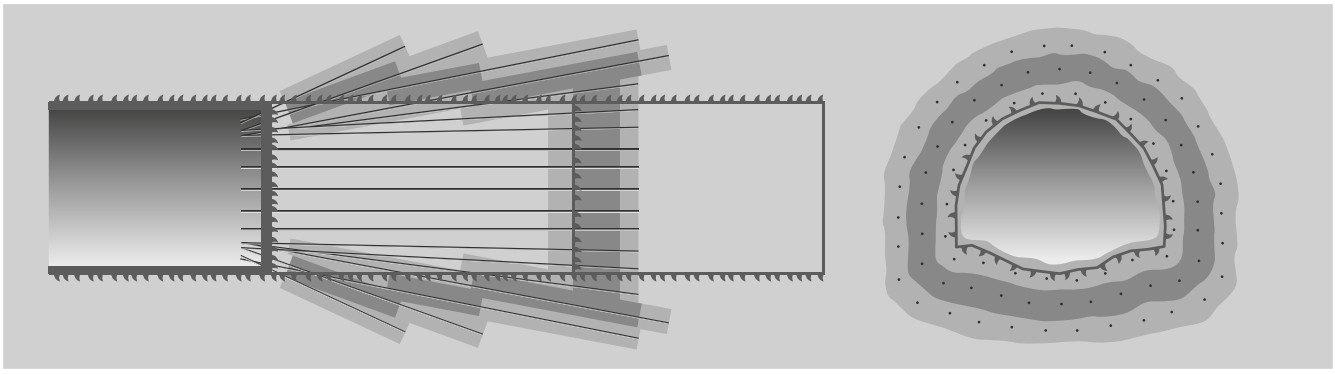
Contrary to the design of ground support elements, the application of injection chemicals can rarely be planned in advance.

Certain default applications where access to the future application site, excavation dimensions, and other influencing factors are known – such as filling of identified cavities or sealing of segmental linings – can be scheduled and prepared in advance.

The unknown part in each underground construction are unpredictable ground and groundwater conditions, which might lead to a so-called emergency application situation. For an emergency application, project-specific method statements for mastery of challenging conditions must be prepared.

Influencing factors of the design include the magnitude (size) of application area, underlying ground conditions, temperature, water flow rate, and pressure.

Data acquisition and a sound probing approach are key to gain further information for the preparation of an emergency method statement.



Technology

Over the past decades, injection chemicals for underground and civil engineering applications have undergone major development and improvement.

One key aspect was the diversification of the portfolio through the development of new products and systems with optimized adaptation to specific injection applications.

The toolbox of today's injection resins also shows enhanced performance characteristics, thanks to the advancement of chemical raw materials and compounds.

Besides an enhancement in the mode of action, state-of-the-art injection resins feature a significant reduction of the environmental impact, for example in terms of groundwater compatibility.

Beside the improvement of injection chemicals, the entire application chain has been improved continuously. Hoses, fittings, and valves have been enhanced; tailored mixing elements ensure a sound interaction of single components. Standardized handling procedures ensure a safe and reliable working process.

Equipment and Accessories

- Case-specific design and dimensioning
- Supply of package solutions
- Wide range of toolbox accessories

Selection and Design Criteria

Product Properties

Introduction

There are several parameters used for describing the properties and assessing the suitability of injection resins in terms of their proper application.
These parameters include reactivity, viscosity, reaction time, mechanical properties, adhesion, foamability, and water miscibility – just to mention the most important ones. They determine the scope of use of a certain resin system and, even more importantly, the success of the application.

Undoubtedly, a detailed parameter analysis has to be an integral part of each case study in order to achieve the intended purpose of the application, i.e. sealing, consolidation, filling, or bonding.

Setting Time

Setting time is the system parameter which shows the reactivity of the material, e.g. the point when the reacting liquid stops to flow. After that time the material starts to set, i.e. the hardening process begins to develop.

Setting time can vary from seconds to hours. Practically, the systems are divided into fast, medium, and slow. Setting time mainly affects the penetrability of the ground and the ability to stop water inflow or outflow.

Another term commonly used is tack free time, which defines the point when the surface of the reacting resin is becoming non-sticky.

Viscosity

Viscosity is one of the physical parameters which characterizes both single components and reacting mixture.
The higher the viscosity of the components the higher is the flow resistance, thus this factor is important for the correct selection of pumps and pumping accessories regarding the pumping pressure.

Viscosity is also an important parameter considering the relationship between the crack size, pumping pressure, and penetration distance.

There is a direct correlation between viscosity, pumping pressure, and pumping volume.

Thixotropy

Thixotropy describes a fluid which can be thick or viscous under static conditions and flows, or become less viscous when sheared or mixed. The pseudo-plastic behavior is a specific case of thixotropy, where the liquid regains high viscosity nearly immediately as the shear force is reduced.

A pseudo-thixotropic behaviour of the liquid material can also be featured by the specific reaction control when the gelling is well separated from the solidification process.

Thixotropic behavior is necessary in any overhead application to stop outflow of the material during and after grouting.

Another important role of thixotropy is surface spraying in terms of coatings and membranes.

Foaming Properties

For polyurethane and silicate resins, the ability to foam is the characteristic feature of the injection system.

Specific formulations allow to control the foaming factor and the foam cell structure – to receive an open or closed cell foam. The following rules of thumb apply: the higher the foaming factor, the lower the mechanical properties and cost of unit volume filling.

The higher the content of the closed cells, the better the water tightness of the foam.

Open cell foams are mainly used for temporary applications.

Water Reactivity

The presence of water in the area of application always affects the effectiveness. Water presence must be considered in a range of aspects during the material selection process:

- Chemical reactivity with the components
- Physical modification of the material
- Water temperature
- Water inflow or outflow
- Water pressure

Mixing of Components

The majority of commonly used materials are two component systems. To obtain the final product, the components have to be pumped to the application zone, where separated components have to be mixed. The effectiveness of the component's mixing determines final material properties and reaction parameters.

The mixing process takes place during the flow through a static mixing element. Design of static mixers may differ for various resin components.

Therefore, this item is carefully selected and checked by the material developer – the end user should respect indications of the injection chemical manufacturer.

Mechanical Properties

Mechanical properties are distinct features of injection materials, e.g. compressive, flexural, or tensile strength. Compact or limited foaming materials are notable stronger compared to foamed materials. With an increasing foaming factor, the compressive strength will decrease consequently.

If the purpose of the injection is the strengthening of the injection area (roof, ribs, slabs, concrete, or masonry structure), mechanical parameters are the most crucial ones.

Adhesion to the Substrate

Adhesion is also an important factor in case of ground consolidation/stabilization and surface application. It can remarkably improve the target result of the application. Ground improvement, consolidation, and anchoring are good examples.

In all cases adhesion increases the technical properties.

Application Range

Once the application (or multiple applications) for an injection project is defined, selection of proper resin type(s) for a given application is the key. SCR resins are used for small-scale grouting works under manageable conditions. 2-component PUR and SIL injection resins can be used for a variety of applications. DSI Underground offers various different product characteristics to ensure an optimum injection result.

In mechanized Tunneling, SIL or ACR type injection resins may be the preferred selection due to their characteristics during mechanical removal or temporary excavations.

An initial estimation of a suitable product range can be accomplished based on water pressure conditions and ground fracture magnitude.

Injection Resin Application Range

Product	Resin Version	Water Presence				Ground Fracture Magnitude				
[–]	[–]	Dry	Moist	Wet	Pressurized	Crack Width [mm]				
						0,05	0,1	0,5	5	10
PUR (2C)	W									
	WF									
	WT									
	S									
	LV									
	HF									
SCR (1C)	1C-50									
	1C-100									
	1C-400									
SIL (2C)	Bond									
	Bond T									
	Fill									
ACR	SR									
	E									

Abbreviations

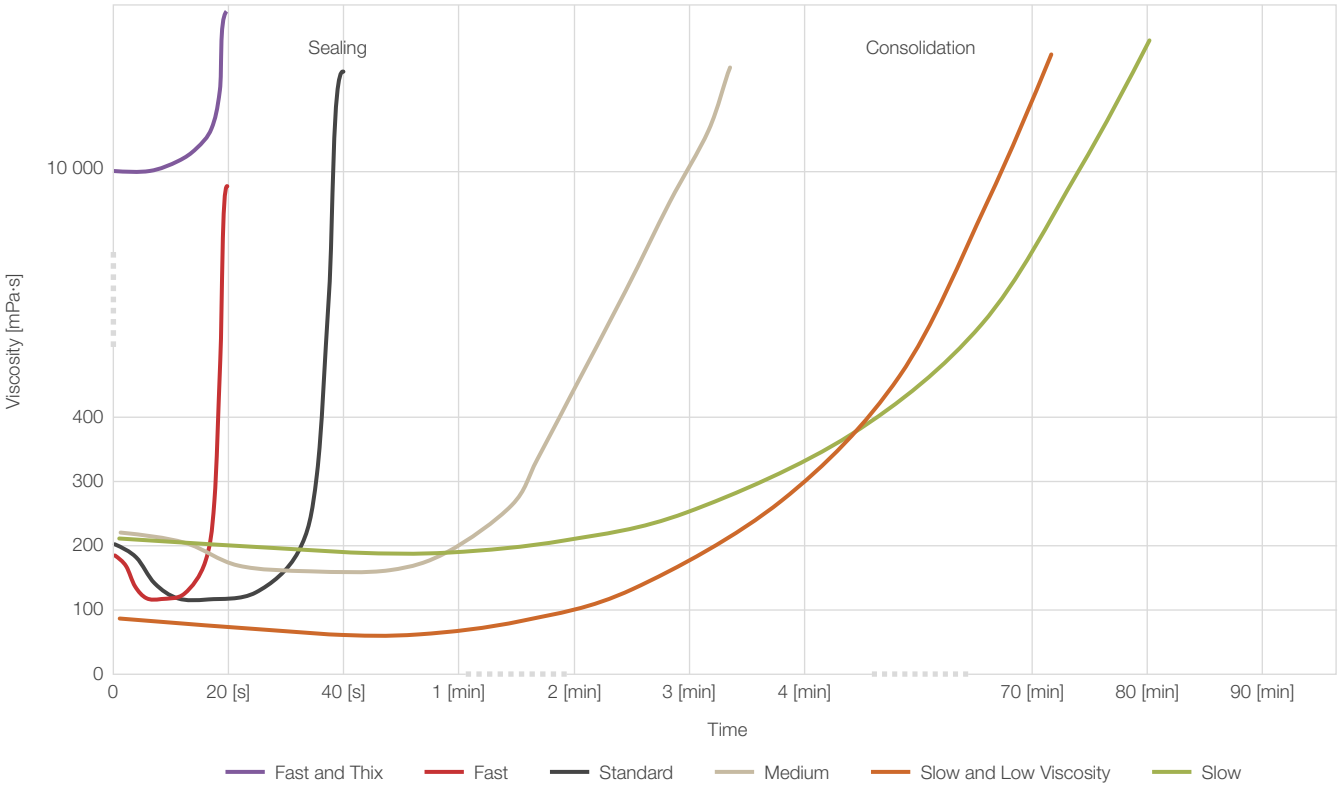
W Water
SCR / 1C Single-Component
LV Low Viscosity
F Fast
S Slow
T Thixotropy
HA High Adhesion
HF High Foaming
HS High Strength
SR Semi-Rigid
E Elastic

DSI Inject Polyurethane Resins (PUR)

Product Range

Product Designation	Product Name	Product Description
Fast setting polyurethane resins	PUR W	– Fast setting resin – 100% solid system (solvent free) – Well balanced and adjusted viscosity of the components – Low initial viscosity after mixing – Easy to mix at different temperatures – Excellent mechanical properties – Good adhesion to the substrate in wet and dry conditions – Insignificant environmental impact
	PUR WF	– Faster version of PUR W
	PUR WT	– Thixotropic version of PUR W
	PUR HS	– Very fast setting resin – 100% solid system (solvent free) – Well balanced and adjusted viscosity of the components – Excellent enhanced mechanical properties – Good adhesion to the substrate in wet and dry conditions
Medium and slow setting polyurethane resins	PUR HA	– Medium setting resin – 100% solid system (solvent free) – Well balanced and adjusted viscosity of the components – Easy to mix at different temperatures – Good mechanical properties – Good adhesion to the substrate in wet and dry conditions – Sound resin flow ability
	PUR S	– Very slow setting resin – 100% solid system (solvent free) – Well balanced and adjusted viscosity of the components – Low initial viscosity after mixing – Easy to mix at different temperatures – Excellent mechanical properties – Good adhesion to the substrate in wet and dry conditions – Insignificant environmental impact
	PUR LV	– Very slow setting resin – Well balanced and adjusted viscosity of the components – Extremely low initial viscosity – Easy to mix at different temperatures – Good adhesion to the substrate in wet and dry conditions
Fast setting polyurethane foam resins	PUR HF-10 PUR HF-15	– Fast setting resin – 100% solid system (solvent free) – Easy to mix at different temperatures – Good adhesion to the substrate in wet and dry conditions – Insignificant environmental impact – Strong foaming system
Accelerator (modifier) for two-component polyurethane resins	Add Fast	– Additive for two-component polyurethane resin – Used when a faster reaction is needed due to high water ingress or low temperature conditions
	Add Thix	– Additive for two-component polyurethane resin – Increases initial viscosity after mixing which can be useful for decreasing resin leakage in heavily fractured ground or in case of massive water ingress

Properties: Viscosity and Setting Time



Specifications

Product	Properties / Unit [1]			
	Viscosity after Mixing	Reaction Start Time	Tack-Free Time	Foam Factor
[–]	[mPa·s] / [cP]	[s]	[s]	[1]
PUR W	210	5	35	≈ 1
PUR WF	210	5	25	≈ 1
PUR WT	> 5 000	5	35	≈ 1
PUR HS	360	5	25	≈ 1
PUR HA	450	25	75	≈ 2
PUR S	210	240	4 800	≈ 1
PUR LV	100	5	4 200	≈ 1
PUR HF-10	460	35	90	≈ 10
PUR HF-15	510	20	135	≈ 15

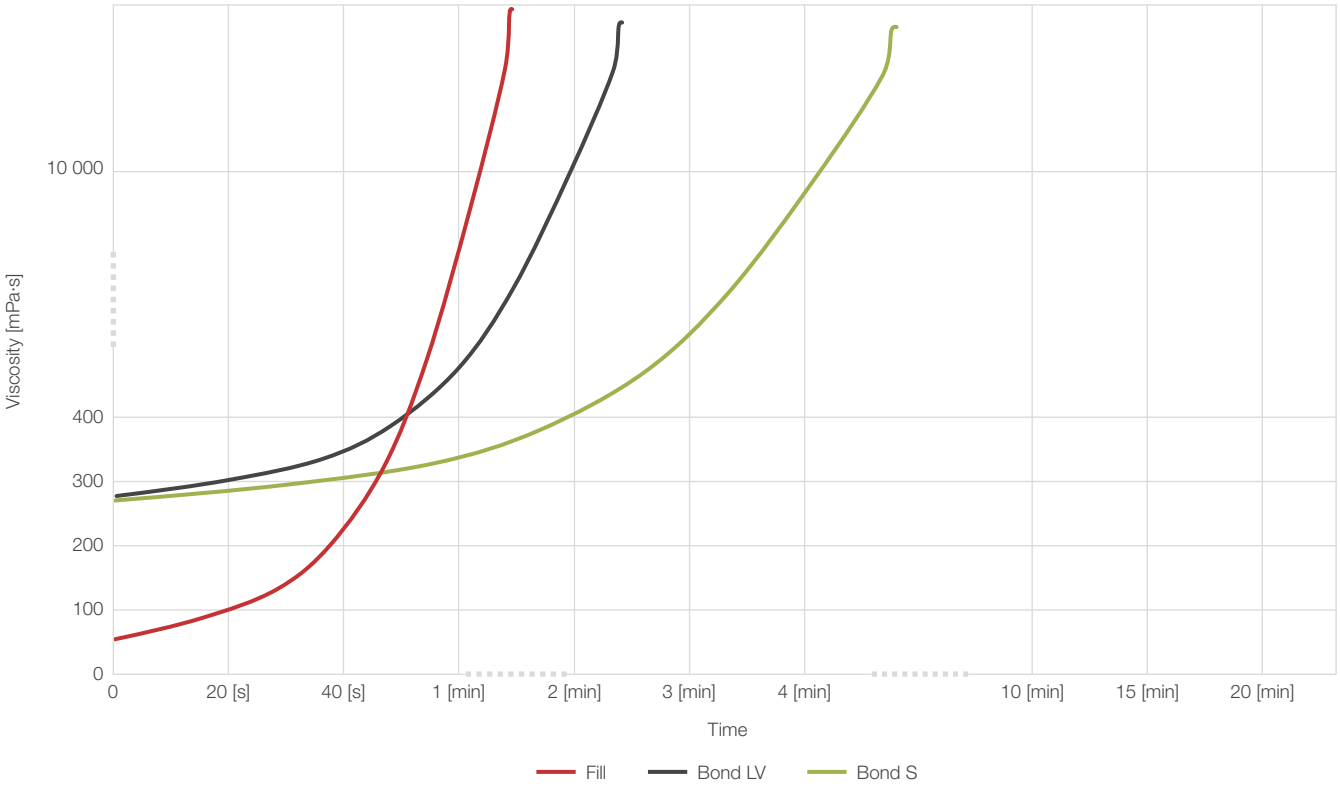
1) The indicated values are laboratory values and may deviate on site. 20 [°C] (68 [°F]).
Store in original packaging, protected from moisture, and at temperatures between 5 [°C] and 30 [°C] (41 [°F] and 86 [°F]).
Data on dosage of accelerators (modifiers) as well as further mixing ratios and information relevant for the application can be found in technical data sheets of DSI Underground.

DSI Inject Organo-Mineral Silicate Resins (SIL)

Product Range

Product Designation	Product Name	Product Description
Organo-mineral silicate resins	Bond LV	– Medium setting resin – Low viscosity of the components – Relatively low initial viscosity after mixing – Sound mechanical properties – Very good adhesion to the substrate in wet and dry conditions – Does not react with water and water does not affect material properties – Excellent corrosion protection
	Bond S	– Slower version of Bond LV
	Bond T	– Thixotropic version of Bond LV – System with increased initial viscosity after mixing – Excellent for applications in heavily fractured ground
Organo-mineral silicate foam resins	Fill	– High foaming injection resin – Very low viscosity of the components – Very low initial viscosity after mixing – Cured resin is easy to cut and drill through – Does not react with water and water does not affect material properties – Excellent corrosion protection
	Fill S	– Slower version of Fill

Properties: Viscosity and Setting Time



Specifications

Product	Properties / Unit [1)]			
	Viscosity after Mixing	Reaction Start Time	Tack-Free Time	Foam Factor
[–]	[mPa·s] / [cP]	[s]	[s]	[1]
Bond LV	300	120	180	1,0
Bond S	300	240	400	1,0
Bond T	450 - 10 000	120	180	1,0
Fill	75	15	45	30 - 40
Fill S	75	40	135	30 - 40

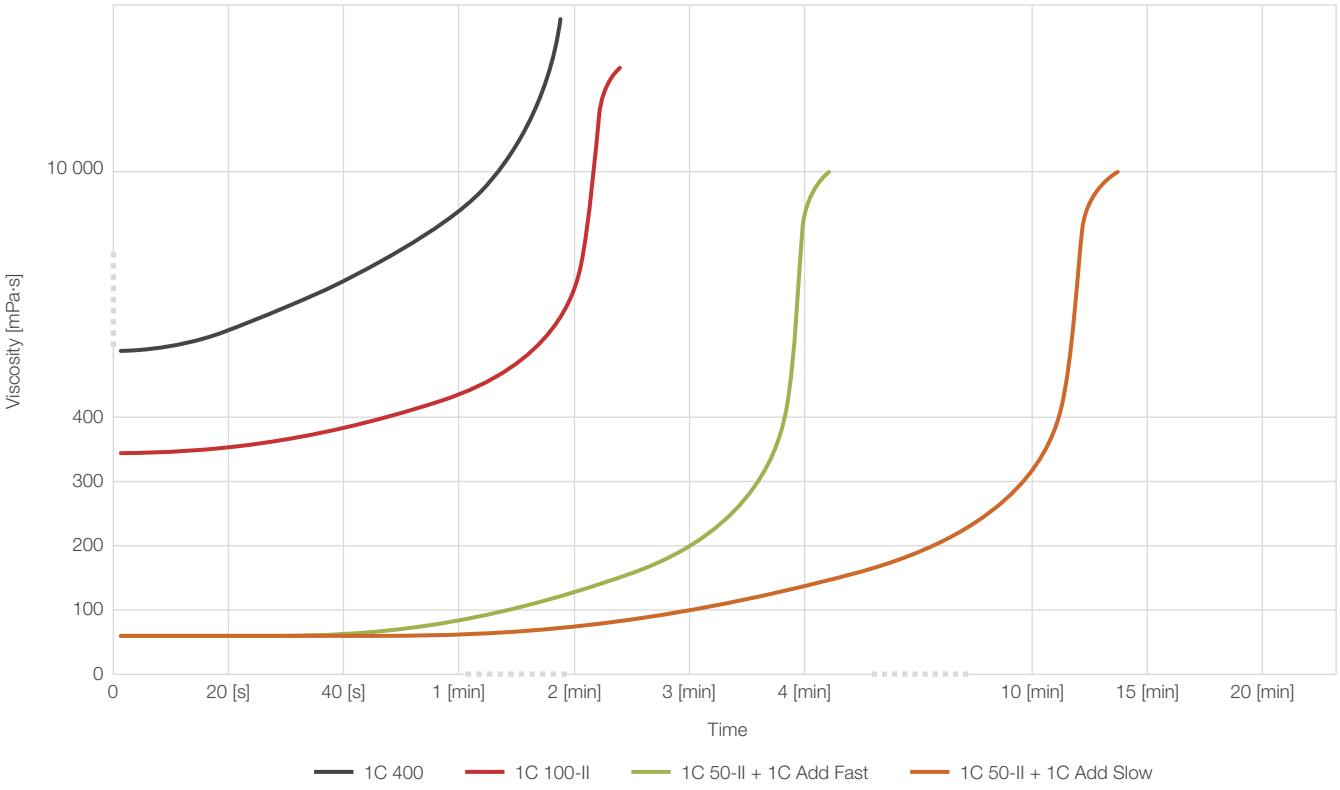
1) The indicated values are laboratory values and may deviate on site. 20 [°C] (68 [°F]).
Store in original packaging, protected from moisture, and at temperatures between 5 [°C] and 30 [°C] (41 [°F] and 86 [°F]).
Data on further mixing ratios and information relevant for the application can be found in technical data sheets of DSI Underground.

DSI Inject Single-Component Resins (SCR)

Product Range

Product Designation	Product Name	Product Description
Single-component resins (SCR)	General	– 100% solid systems – solvent-free – Slow to fast setting resin with adjustable reaction time – Phthalate-free – Sound mechanical properties of the consolidated ground – Insignificant environmental impact
	PUR 1C 50-II	– Slow setting resin – Very low initial viscosity – Product designed for fine sand injections
	PUR 1C 100-II	– Rigid and medium setting resin – Setting time can be increased using 1C Add Fast – Can be used in a wide temperature range – Insignificant environmental impact
	PUR 1C 400	– Elastic and medium setting resin – Setting time can be increased using 1C Add Fast – Insignificant environmental impact
Accelerator for single-component resins	1C Add Fast 1 C Add Slow	– Additive for single-component polyurethane resins – Used when faster or slower reactions are required to cope with high water ingress or low temperature conditions

Properties: Viscosity and Setting Time



Comparison of Single-Component and Two-Component Resins

- Easier application of SCR systems
  - No static mixer required
  - Faster and simpler cleaning procedure
- New SCR system featured by DSI Underground
  - Special integrated accelerator customized for project requirements available upon request
- Limitations of SCR systems
  - Mostly lower pumping rates [L/min]
  - 2-C systems are more flexible in regards to material parameters and potential applications and have enhanced material properties

Specifications

Product	Properties / Unit [1]				
	Reaction Start Time [s]		End of Foaming [s]		Foam Factor
[–]	10 [°C] / 50 [°F]	20 [°C] / 68 [°F]	10 [°C] / 50 [°F]	20 [°C] / 68 [°F]	[1]
PUR 1C 50-II [2]	80	55	350	180	≈ 5
PUR 1C 100-II [2]	45	13	230	150	≈ 35
PUR 1C 400	55	20	300	160	≈ 20

1) The indicated values are laboratory values and may deviate on site.
Store in original packaging, protected from moisture, and at temperatures between 5 [°C] and 30 [°C] (41 [°F] and 86 [°F]).
Data on dosage of accelerators (modifiers) as well as further mixing ratios and information relevant for the application can be found in technical data sheets of DSI Underground.

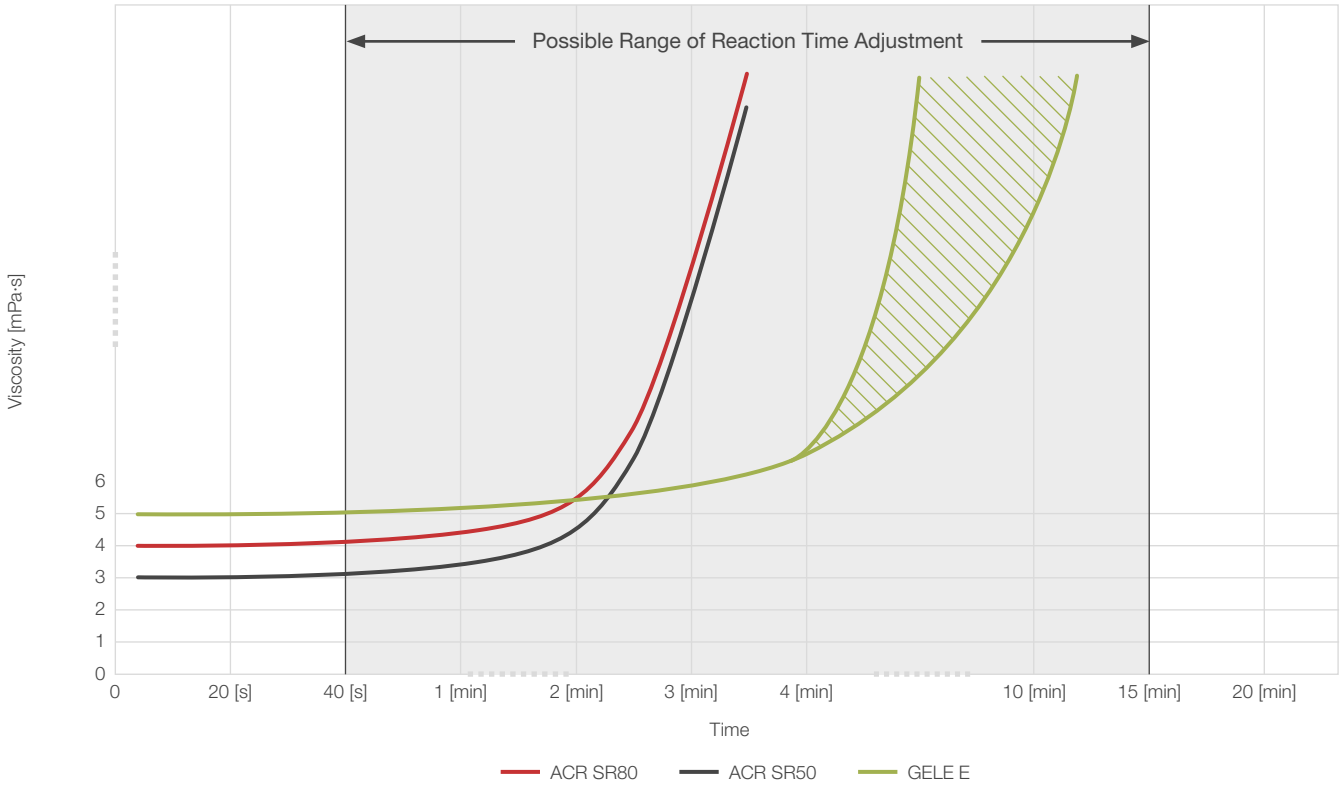
2) Reaction times with 0,5% Add Fast 1C.

DSI Inject Acrylic Resins (ACR)

Product Range

Product Designation	Product Name	Product Description
Acrylic injection resins	General	– Low viscosity water solutions of acrylic monomers – Extremely low initial viscosity of mixed components – Easy to mix at different temperatures – Insignificant environmental impact – Excellent penetration and sound adherence
	ACR SR 80	– 4-component system – High-strength resin featuring easily controlled gelling – Excellent mechanical properties and rigid system – Suitable for injection of fine sands
	ACR SR 50	– 3-component system – Medium strength featuring easily controlled gelling – Excellent mechanical properties and rigid system – Suitable for injection of fine sands
	GELE E	– 3-component system – Rubber-like acrylic resin – Suitable for ground stabilization and water sealing

Properties: Viscosity and Setting Time



Special Features

- 3-component polyacrylate injection gel
- Efficient sealing against ground water
- So-called “curtain sealing”: waterstop by forming an impermeable layer of sealant in the ground (multiple steps)
- Constant foam volume with factor 1

Specifications

Product	Properties / Unit [1]				
	Viscosity after Mixing	Reaction Time [2]	Mixing Ratio: Parts per Volume	Foam Factor	Compressive Strength [3]
[–]	[mPa·s] / [cP]	[s]	[–]	[1]	[MPa] / [ksi]
ACR SR 80	4	30 - 360	1 : 1	1	≈ 20 / ≈ 2,90
ACR SR 50	3	60 - 300	1 : 1	1	≈ 10 / ≈ 1,45
GELE E [4]	4 - 6	240 - 720	1 : 1	1	N/A

1) The indicated values are laboratory values and may deviate on site.
Store in original packaging, protected from moisture, and at temperatures between 5 [°C] and 30 [°C] (41 [°F] and 86 [°F]).
Data on further mixing ratios and information relevant for the application can be found in technical data sheets of DSI Underground.

2) Start of gelling.

3) With sand.

4) Hardening agent: 0,5% to 5,0%.

Pumps and Accessories

Pumps

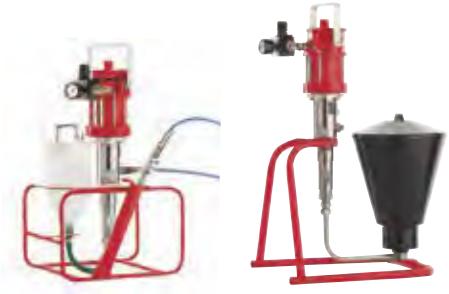
Selection of a suitable high-pressure pump depends on the type of application, available infrastructure, and ground conditions. Availability of existing equipment may also influence equipment selection. DSI Underground offers a wide range of high-pressure pumps for underground and civil engineering applications. Further details are described in separate technical data sheets.

DSI Inject 2-Component High-Pressure Piston Pump

- Brace operated, pneumatically driven piston pump
- 1:1 mixing ratio for processing DSI Inject PUR and SIL Systems
- Independent intake of both components
- Robust design and little susceptibility for damages
- Easy operation and handling
- Spare parts and starter set available
- Technical data sheet and operation manual available upon request

DSI Inject 1-Component High-Pressure Pump

- Small and light-weight aggregate
- Electric or pneumatic versions available
- Different versions for lower and higher injection pressure ranges
- Easy to clean and maintain



DSI Inject 2-Component High-Pressure GEL Pump

- Robust design and little susceptibility for damages
- Additional flushing pump for easy cleaning
- High performance
- Stainless steel pump featuring supreme corrosion resistance
- Double piston pump, pneumatically driven
- Independent intake of both components

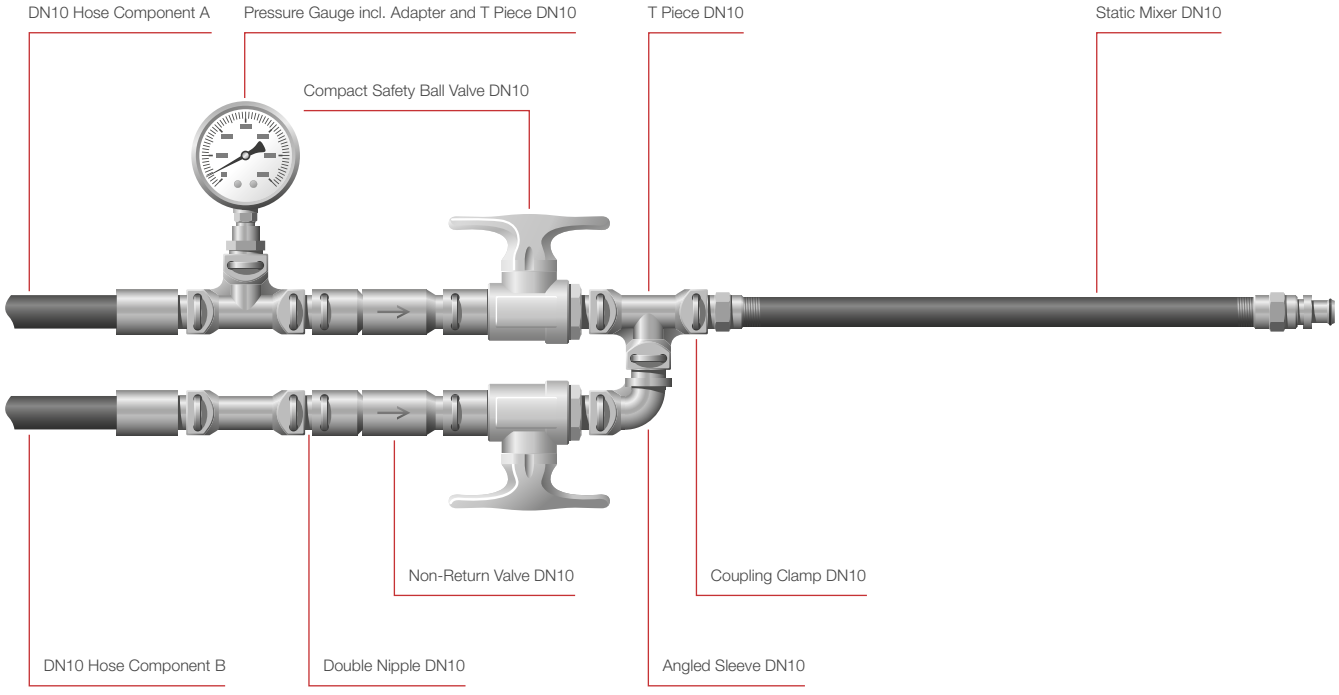
DSI Inject 2-Component High-Pressure Gear Pump

- Adjustable mixing ratio
- High output
- Reliable, long-lasting aggregate for long-term application
- Electrically driven

Accessories

- Mixing tubes and static mixers
- Connectors
  - Injection adapters for DSI Hollow Bar System and GRP hollow bars
  - Quick connectors (cable bolts)
- Screw-on nipples
- DSI Hollow Bar System and GRP hollow bar injection lances
- Steel and plastic injection lances
- Injection deep packers

Mixing Assembly 1:1 (Example)



Emergency Kit

Types of Emergency Kits

- Prepared in advance for standard applications
- Just-in-time system solution: ensures no loss of valuable construction time

DSI Underground as Problem Solver

- One-stop shop: all material from one source
- Quick reaction: contingency material stock and experience in global logistics
- Support throughout all project phases: from initial evaluation to method statement to material supply to on site application

Customized Emergency Kits for Conventional and Mechanized Tunneling

- 10 [ft] or 20 [ft] GP container
- Material: steel and chemical consumables
- Equipment: injection pumps etc.
- Worldwide support by DSI Underground competence centers

Mechanized Tunneling

Emergency Measures for Challenging Ground Conditions

Influencing Factors

- Water ingress
- Instabilities ahead of the face
- Geological overbreak or cavities

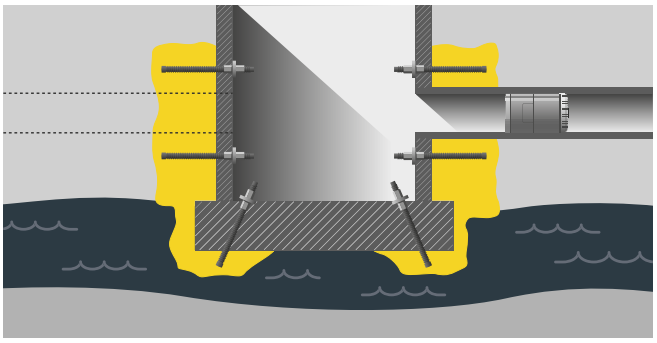
Limitations

- Access of cutter wheel and shield area
- Delay of ground support installation
- Excavation geometry defined by the machine

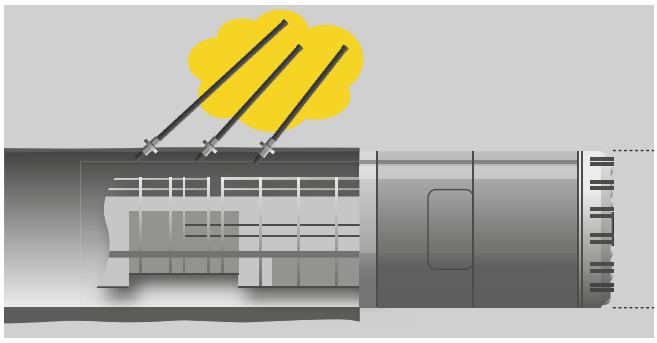
Boundary Conditions

- Application
- TBM type and geometry
- Drilling equipment

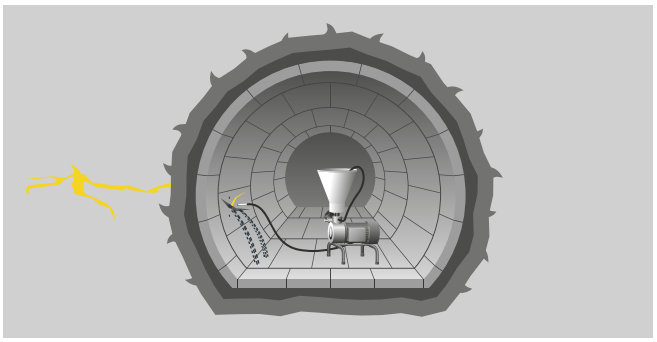
Lowering of Water Ingress



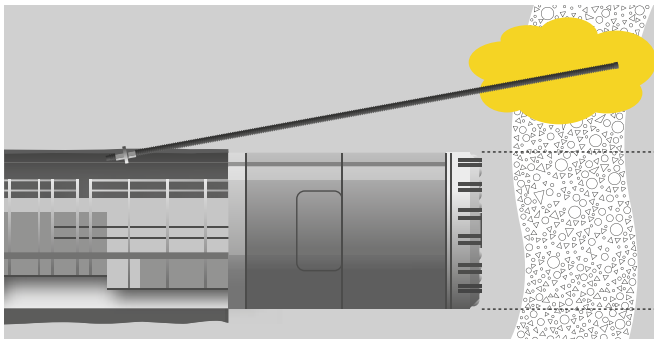
Cavity Filling & Strengthening



Sealing Injections



Injection Pipe Umbrella



AT – 89 TBM Pipe Umbrella System

- Installation with attachment drills
- Drilling works can be executed by standard personnel under the supervision of application engineers
- Time-saving installation due to simultaneous drilling and tubing (self-drilling)
- Installation using a preventer is possible
- GRP or steel pipe length may be adapted to the space available
- GRP injection pipes can be cut by a shield and mucked out via a TBM cutting wheel
- Stabilization of fractured ground or fault zones
- Prevention of water ingress

Backfilling and Repair Works

Backfilling

- Filling of voids in the annular gap between excavation surface and segmental lining
- Limitation of ground material washout
- Secondary sealing effect
- Fast reaction and curing
- Ensuring of long-lasting stability

Repair Works

- Sealing of tunnels (primary lining)
- Shotcrete and concrete sealing repair
- Repair waterproofing (injection hoses or drilled packers)
- Default systems: SCR or slow-setting PUR
- Aging tests prove long lasting durability of cured DSI Inject resin

Approvals and Further References

Approvals

Test Procedures

- Mechanical properties
- Reaction temperature
- Self-rescue filter tests
- Hygienic assessment
- Groundwater compatibility
- Fire testing
- Long-term durability

Approvals

- Product-specific approvals are listed in DSI Underground technical data sheets

Cooperation Partners

- MFPA Leipzig GmbH, Germany
- DMT GmbH, Germany
- Central Mining Institute, Poland
- Hygiene Institute Gelsenkirchen, Germany

Packaging

- Material supply in IBC tanks for large-scale applications
- Steel barrels: 200 [kg] (441 [lbs])
- Default packaging: PVC canisters or steel tins

Further References

- Safety data sheets
- Technical data sheets
- Instructions for mixing and processing, cleaning and disposal, health and safety

Pre-Support and Drainage

Contents

Introduction

The group of pre-support comprises a multiplicity of support elements, which are selected depending on the conditions encountered. They are installed from the actual face in the advance direction into not yet excavated ground and serve for a stable and safe working area during the following excavation steps. Additional drainage measures stabilize the ground by improving its properties.

Pre-support can be divided into two groups: installed in the face area or installed in the outer perimeter of the excavation face. The first group primarily includes face bolts (see catalogue section “Bolts”), while the second group includes forepoling boards, spiles, pipe umbrellas, horizontal jet-grouted columns, and freezing technologies.

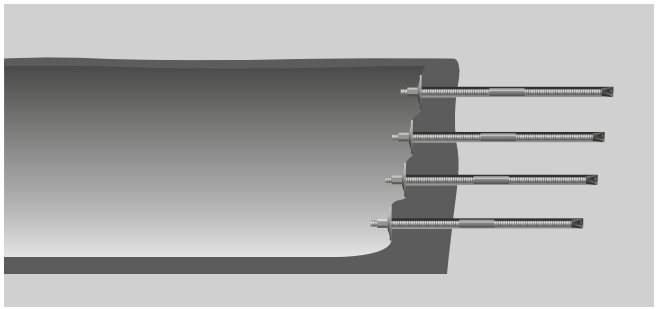
Depending on the geological and geometrical conditions, differing failure mechanisms are expected and therefore differing pre-support measures prove to be the optimum solution for stable and safe tunnel construction works.
The range of possibilities extends from short (3 - 4 [m] or 10 - 13 [ft]) to long (> 15 [m] or 50 [ft]), from pre-drilled holes to self-drilling installation, from one-piece to connected, piece-wise installed support measures. Depending on the present requirements, more than one appropriate option can be selected, which is essential due to the very different possible boundary conditions in the tunnel heading area.

Drainage drilling systems are used for drainage works during construction and in the excavation area. Depending on the requirements, systems with different diameters and installation lengths are available.

Fields of Application

Face Bolts

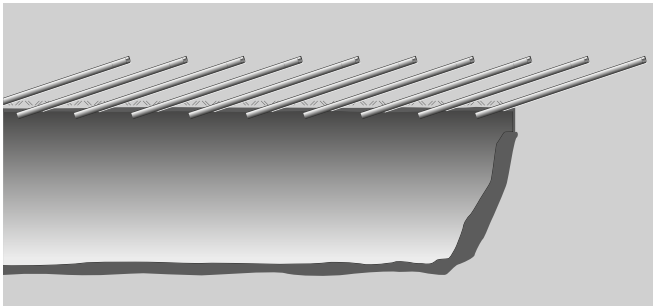
- Unstable face conditions
- Soft ground
- Blocky hard rock
- Mixed face conditions
- Fault zones, sediments, and talus
- Ravelling ground



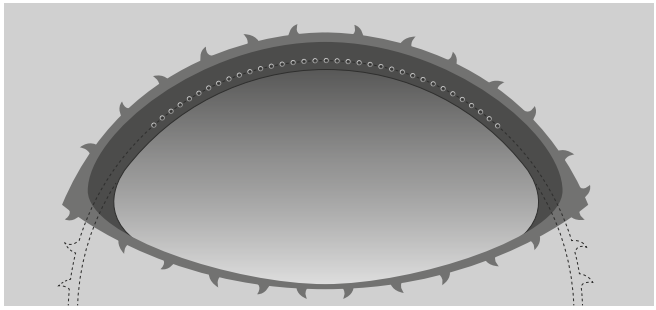
Spiles and Forepoling Boards

- Tunneling in soft homogeneous or inhomogeneous ground
- Fault zones, sedimentary ground, or debris
- Blocky and jointed rock mass
- Nearly non-cohesive soil

Spile Support



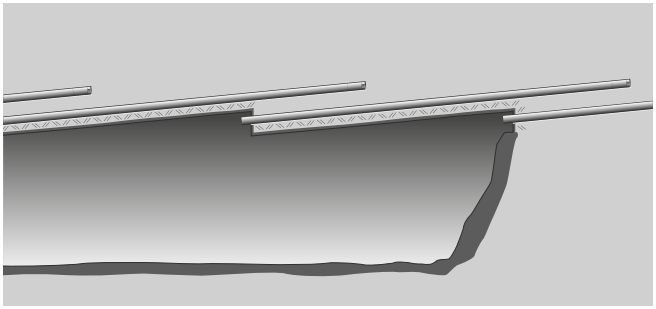
Cross-Section



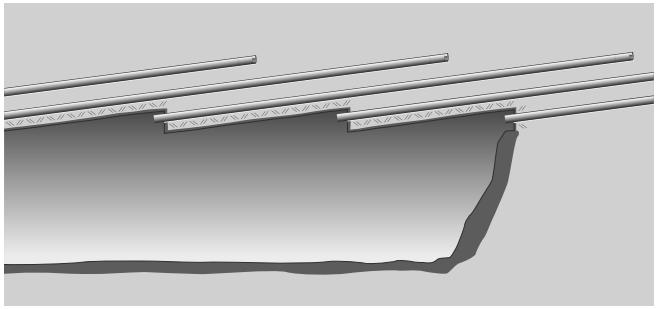
AT – Pipe Umbrella

- Heavily jointed ground
- Soft ground
- Ravelling ground
- Ground prone to subsidence
- Urban Tunneling
- Fault zones, sediments, and talus
- Frequently changing ground conditions
- Portals with relaxed or unknown stress regime and/or joints
- Re-excavation of collapsed tunnel sections

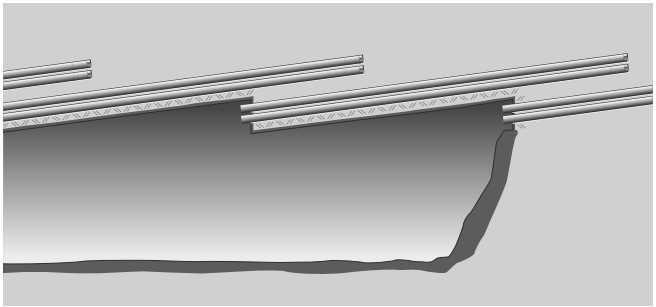
Single AT – Pipe Umbrella



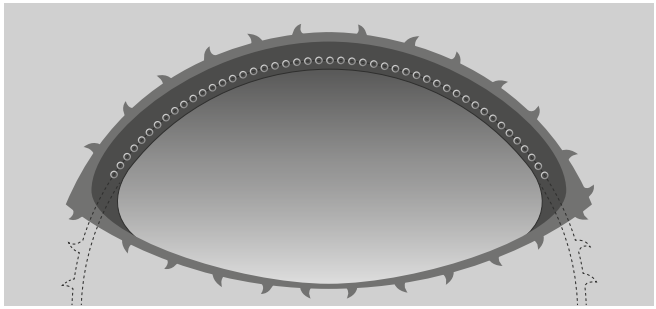
Single AT – Pipe Umbrella with Double Overlap



Double AT – Pipe Umbrella



Cross Section when Excavating under an AT – Pipe Umbrella



Support Effects

Face Bolts

Face bolts are installed in possibly unstable face areas typically in a pre-defined pattern. The bolts are often in the range of 6 - 9 [m] long and continuously bonded to the ground. During excavation, the ground around the bolt is excavated stepwise, the bolt is cut, and the bolt plates are fixed again. So, without continuous bonding the bolt can fully relax and loose its support effect temporarily.

Face bolts can either be loaded by shear force in case of block sliding or a discrete shear plane in weak ground, or are exposed to longitudinal tension forces. A combination of both loading scenarios is also very often the case. Hence, bolt types with a continuous bonding to the ground as well as the possibility to re-mount the bolt head are more effective for face bolting.

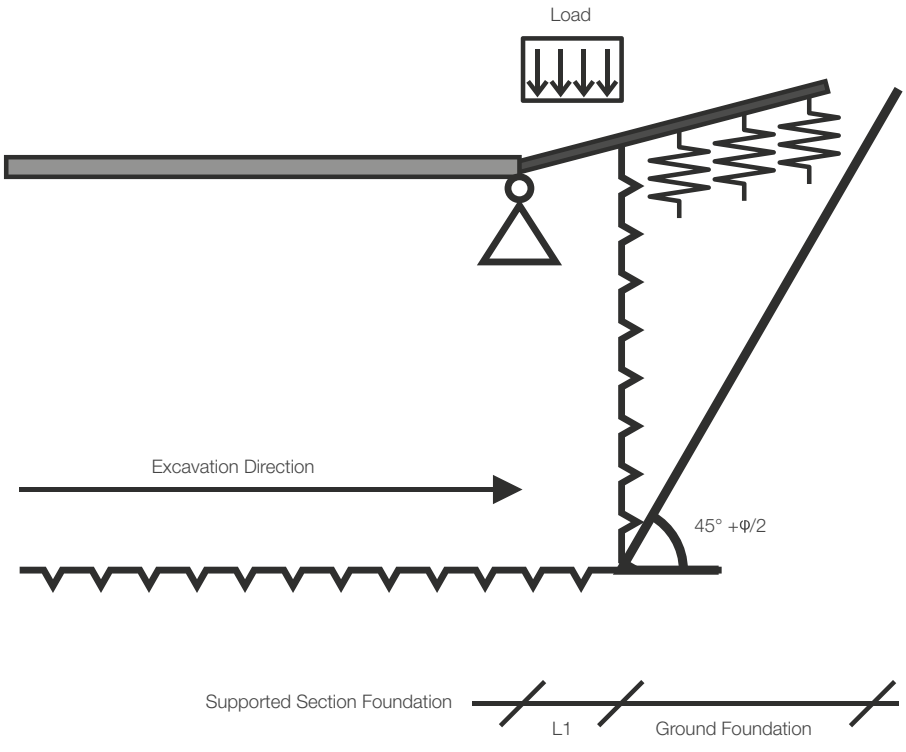
So the shear resistance as well as the elastic tension force are relevant design parameters.

Common systems used for face bolting are continuously bonded, which are described in the catalogue section “Bolts”: DSI Hollow Bar System, GRP bolts, and rebar bolts.

Spiles

Spiles are installed at the outer perimeter of the heading to the ground ahead of the face. Typically, a spile is installed with a low (10° to 20°) outward inclination either through a lattice girder or above any other steel beam type. The most common spile length is 4 [m] (13,1 [ft]).

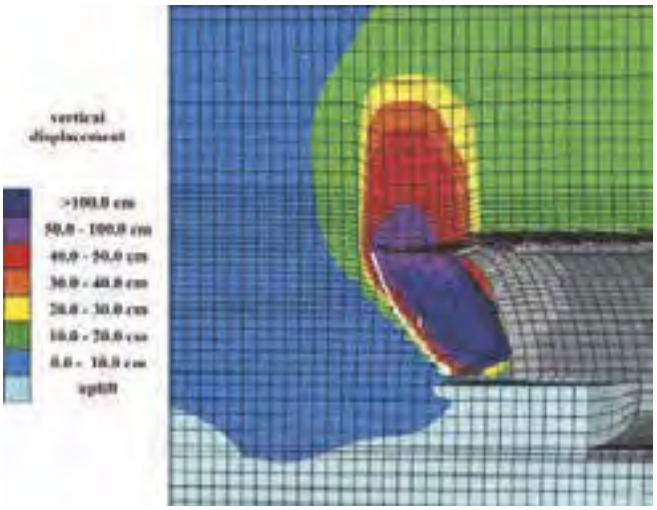
Spiles subdivide the perimeter of the open span and hold back the material on the outside. These loads are transferred in the longitudinal direction to its foundations, the ground ahead of the face and the steel beams. This effect supports the outer perimeter of the open span but additionally loads the face. In blocky material, spiles are exposed to shear loads while in weak ground spiles are bent. Depending on the load scenario, the relevant design parameter must be defined.



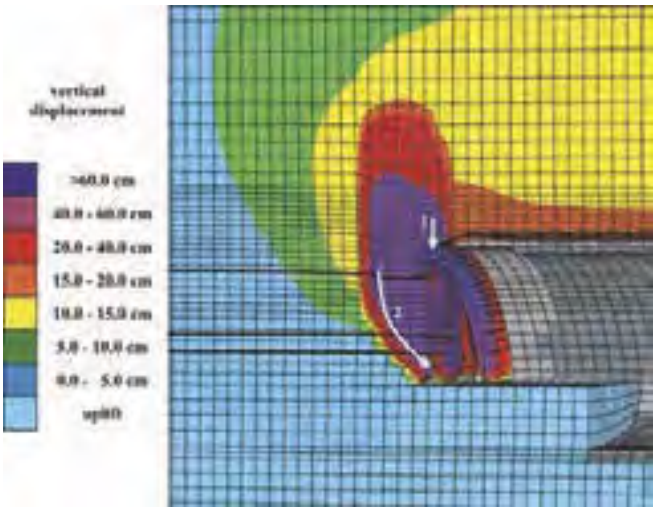
Volkmann (2016)

Combined Support Action

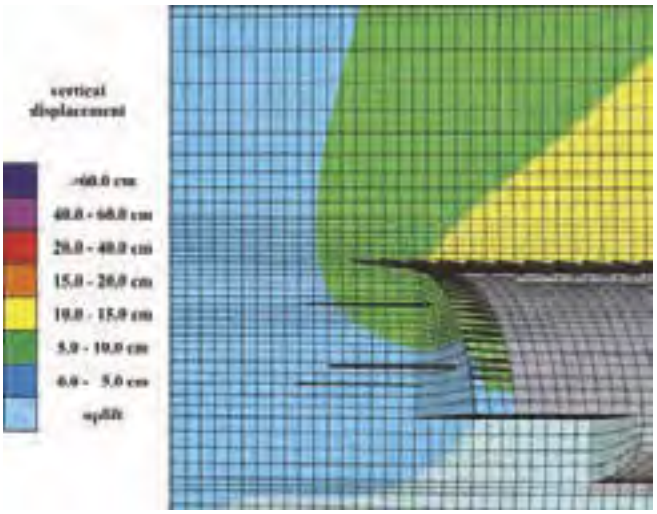
Failure due to the Lack of Face Bolts



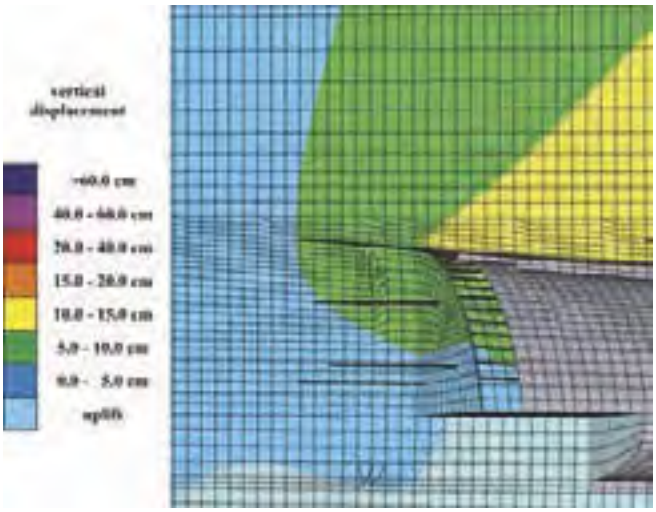
Failure due to the Lack of Forepoling



Stable Situation – Face Bolts and Spiles



Stable Situation – Face Bolts and AT – Pipe Umbrella



Volkmann (2009)

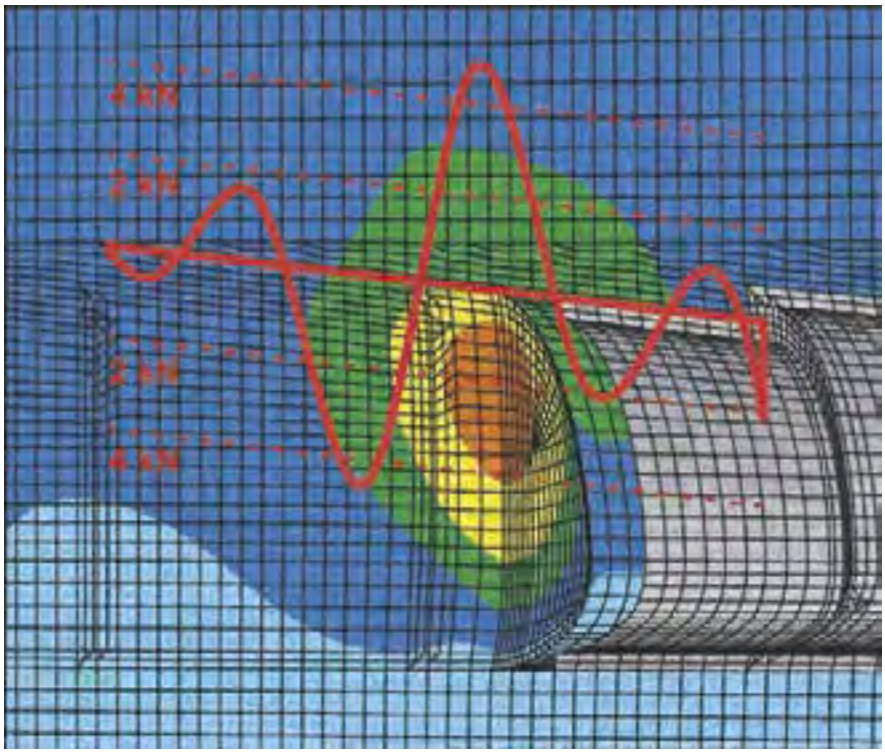
AT – Pipe Umbrella

The growing population in metropolitan areas requires a continuous upgrade of underground infrastructure. In these areas, ground is typically composed of fluvial deposits or highly weathered rock, where tunnelling induces subsidence. New tunnel construction projects are often ruled by restrictions regarding allowable settlement values. Therefore, extensive and expensive temporary tunnel support measures such as ground freezing, horizontal jet grouting or pipe jacking must be applied to complete these projects.

An economic alternative to these measures is the AT – Pipe Umbrella System, which is also termed the "canopy tube method", or "long fore-poling" in the international arena. It perfectly fills the gap between low-cost normal spiling (forepoling) techniques and the above mentioned expensive support measures, which is why its use in tunnel construction is continuously increasing.

Due to technical developments in drilling techniques, the AT – Pipe Umbrella System can be installed by state-of-the-art drilling machines and on-site tunnel personnel. The mode of action for this support method was extensively studied by scientific site investigation, laboratory tests, and numerical calculations.

Support effects and design criteria are described in the catalogue section "AT – Pipe Umbrella System" on page 169.



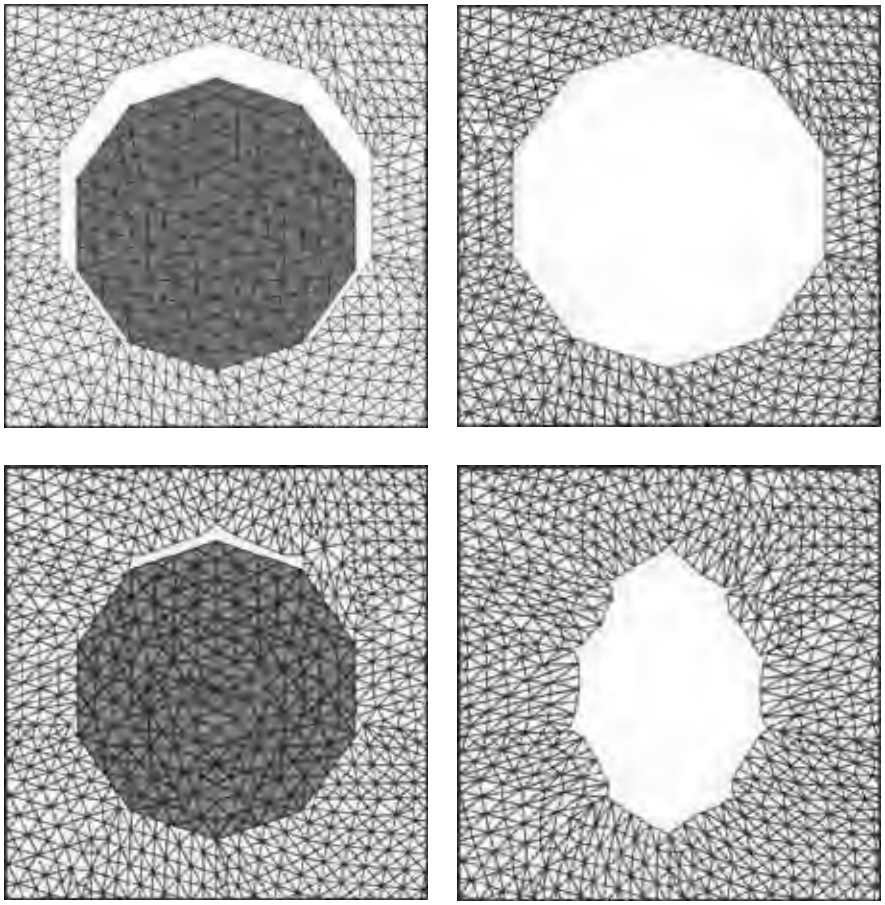
Volkmann & Schubert (2006)

The AT – Pipe Umbrella System is classified in the group of pre-support measures. The pipes are installed at the actual face position to the front parallel to the geometry that is to be excavated later ("fore-poling"). This results in a supporting "umbrella" or "canopy" acting above the working area.
The outer diameter of the steel umbrella pipes is typically between 60 [mm] and 200 [mm] (2,4 [in] and 7,9 [in]) with a wall thickness ranging from 4 [mm] to 10 [mm] (5/32 [in] to 25/64 [in]). Today, the length of one pipe umbrella is 12 [m], 15 [m], or 18 [m] (39,4 [ft], 49,2 [ft], or 59 [ft]) with a remaining foundation length in the ground in the longitudinal direction of 3 [m] to 6 [m] (9,8 [ft] to 19,7 [ft]) to ensure load transfer into the ground ahead of the face. The installation requires additional space; consequently, a saw-tooth shaped profile is generated, which is typical for pipe umbrella supported tunnel sections.

Currently, the pipes can be installed by either special machines or conventional drill jumbos. Basically, there are two installation methods – pre-drilling and cased drilling.
When using the pre-drilling method, the first step is to drill a hole, followed by the insertion of the pipe in a second step. The pipes are installed in segments parallel to the drilling process when using the cased drilling method.

Pre-drilling systems induce large deformations, quite often time-consuming re-drilling is required as well. Self-drilling cased systems feature an immediate support of the borehole wall, resulting in moderate deformations and stress relaxations. This ground preserving installation method is preferred in weak ground conditions.

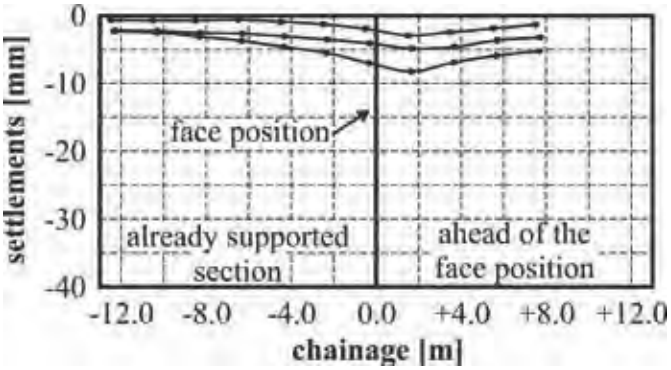
Results from a numerical study in Universal Distinct Element Code (UDEC) illustrate deformation characteristics of the cased drilling system (left) and pre-drilling system (right). Both holes were 150 [mm] (5,9 [in]) in diameter before stability calculation.



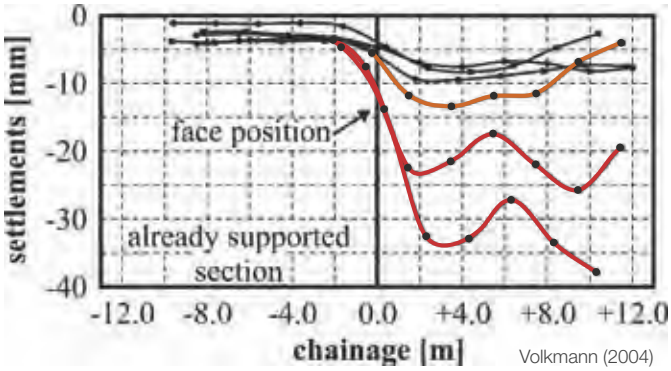
Volkmann (2006)

Settlements During the Installations of Different Pipe Umbrella Systems

Cased-Drilling (Birgltunnel)



Pre-Drilling (Trojanetunnel)



Volkmann (2004)

The AT – Pipe Umbrella System is installed segment by segment because of the limited length of the drill jumbo's drill arm, and for this reason, the pipes must be connected to each other during installation. The type and quality of the coupler is the most important factor in achieving the maximum bearing capacity of the support system. Therefore, three different coupler types are available for the AT – Pipe Umbrella System: the standard threaded connection, the squeezed connection, and the nipple connection. These connection types are mainly distinguished from each other by their stiffness and strength properties in relation to the pipes' full section. The standard threaded connection is ideally suited for installing measurement instrumentation or ground improvement because the inner diameter stays constant.

On the other hand, a typical application area for the threaded nipple coupling would be a project where the pipe umbrella is used for its static supporting effect as well as for its deformation decreasing effect. This ensures a technically ideal solution for every type of application.

Source: Volkmann (2014)

Drainage Drilling Systems

Introduction

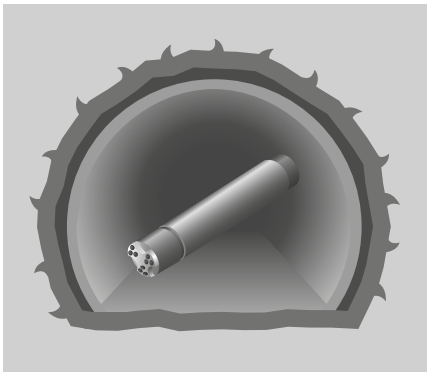
Drainage drilling systems are used for dewatering and ground improvement during construction. In Tunneling, they are commonly used for temporary drainage, hence are also used for semi-permanent applications such as surface drainage of slopes or underground structures. Installation and application is accomplished with standard drilling equipment and on-site personnel. Discharge of the drained water must be accomplished in a controlled way limiting further ground penetration. Application of a vacuum pump system linked to the drainage drilling systems is an optional active measure in ground with low hydraulic permeability.

There are two common systems available:

- AT – TUBESPILE™ Vacuum Lance
  - Drainage of water in the vicinity of the tunnel perimeter
  - Installation length: 3 [m] to 5 [m] (9,8 [ft] to 16,4 [ft]), depending on the length of the drill feed
  - Uncoupled, single-pass system
  - Improvement of ground properties by reduction of the water content
- AT – Drainage System
  - Far-ranging drainage
  - Installation length: 12 [m] to 30 [m] (39,4 [ft] to 98,4 [ft]), longer drainage drills are possible, depending on installation equipment and ground conditions
  - Coupled, cased drilling system
  - Profound water drainage ahead of excavation in a safe distance of the tunnel drive

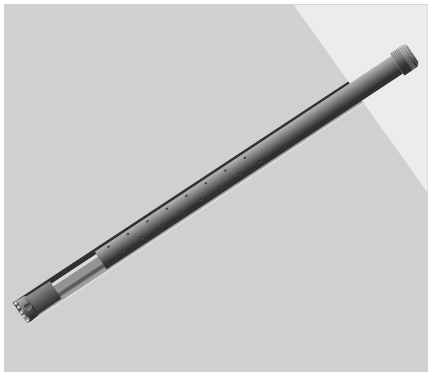
Installation of drainage drilling system is commonly accompanied by installation of pre-support systems such as the AT – Pipe Umbrella System, or application of injection chemicals for ground consolidation or waterproofing.

Fields of Application



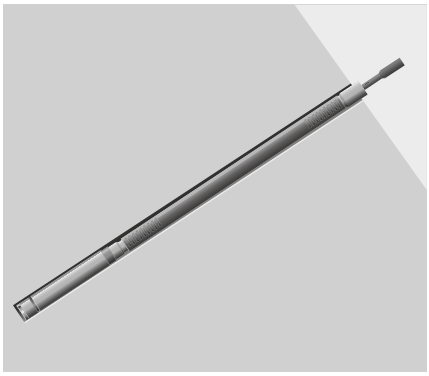
Drainage Drilling Systems

- Stabilization of water-saturated slopes
- Reduction of the water pressure behind construction walls
- Drainage works in challenging ground conditions



AT – TUBESPILE™ Vacuum Lances

- Drainage works around the excavation
- Drainage with and without vacuum application
- Safe and efficient reduction of the local groundwater pressure



AT – Drainage System

- Far-ranging drainage works
- Drainage of the ground ahead of the advance and parallel to construction
- Reduction of water pressure in fault zones ahead of excavation

Spiles

Hollow Bars

Introduction

DSI hollow bar self-drilling spiles form a part of the DSI Hollow Bar System product range. They are ideal for pre-support measures in all ground types. Especially for unstable boreholes, the fast and self-drilling installation offers distinct advantages compared to conventional spile types.

DSI hollow bar self-drilling spiles support local instabilities in the working area. In poor ground, this system is an excellent alternative to conventional rebar spiles or tubular spiles.

Main Advantages

- Installation using conventional drilling machines
- Secure, simple, and fast installation
- Unproblematic application in case of unstable boreholes
- Spile drilling and spile installation in one step
- Greater spile lengths can be achieved with couplings
- Optional grout injection through the hollow bar

System Description

DSI hollow bar self-drilling spiles are installed with conventional drill jumbos using rotary percussive drilling.
The installed hollow bar simultaneously serves as drilling rod and pre-support element. The drilling energy is transferred onto the drill bit, which has a larger outer diameter than the hollow bar and the coupling.

Cooling and back-flushing of cuttings is accomplished with water between the borehole wall and the DSI hollow bar self-drilling spile.

System Components

- DSI hollow bar self-drilling spile, optionally available with injection holes
- Optional couplings for extension
- Spile drill bit or welded-on drill bit

Specifications

Characteristic Value / Type [1]	Unit	R32-210	R32-400	R38-420	R38-550	R51-550	R51-950
Actual external diameter	[mm]	31,1		37,8		49,8	
	[in]	1,22		1,49		1,96	
Delivery lengths [2]	[m]	2,0 - 6,0					
	[ft]	6,6 - 19,7					
Modulus of elasticity	[N/mm²]	205 000					
	[ksi]	29 700					
Moment of inertia [3]	[cm⁴]	3,0	3,9	7,8	18,6	20,4	23,9
	[in⁴]	0,07	0,09	0,19	0,43	0,49	0,57
Maximum moment (elastic) [4]	[kN·m]	0,9	1,5	2,2	2,5	4,2	6,2
	[lbf·ft]	665	1 100	1 625	1 845	3 100	4 570

1) Further technical information is included in the catalogue section “DSI Hollow Bar System”.

2) Off-size lengths are available upon request.

3) Calculated with the average internal diameter and the nominal cross-sectional area, rounded.

4) Rounded.

Installation Procedure

1. Assembly of the DSI hollow bar self-drilling spile and connection with the hydraulic rock drill.

2. Rotary-percussive self-drilling installation without casing: single-use drill bit and hollow bar serving as drilling rod; flushing with air, water, or an air-water-mixture.

3. Optional extension with couplings.

4. Decoupling from the drifter, optional subsequent grouting using an injection adapter.

Technical Features

- Comprehensive drill bit portfolio for different ground conditions
- Grouting of the annular gap ensures the load transmission and load-bearing capacity
- Optionally with injection holes for ground improvement

AT – TUBESPILE™

Introduction

The AT – TUBESPILE™ forms part of the POWER SET product family. It qualifies perfectly as a pre-support system in conventional Tunneling and is classified as a spile.

The application of the AT – TUBESPILE™ permits the stabilization of local instabilities in the excavation area and the prevention of ground loosening induced by installation. In poor ground conditions, this system is a sound alternative to conventional ram spiles, rebar spiles, or DSI hollow bar self-drilling spiles.

Main Advantages

- Installation using conventional drill jumbos
- Secure and easy installation procedure
- Spile drilling and installation in one step
- Ground-preserving, self-drilling installation
- Higher section modulus than comparable rebar spiles

System Description

The AT – TUBESPILE™ is installed in one step through rotary percussive drilling with conventional drill booms. The drill rod inside the spile tube transfers the drilling energy onto the drill bit, which is available as a button drill bit with carbide inserts and as a hardened arc-shaped drill bit. The AT – TUBESPILE™ is pushed into the borehole by an adapter and follows directly behind the drill bit. Cooling, flushing, and transport of cuttings take place inside the spile tube with water.

System Components

- AT – TUBESPILE™ drill bit
  - Single-use drill bit Ø 52 [mm] (Ø 2 3/64 [in]), arc-shaped or button bit version available
- AT – TUBESPILE™
  - Spile tube Ø 51 [mm] (Ø 2 [in])
- POWER SET drill rod
  - Special drill steel for optimum service life
- POWER SET adapter
  - Controlled transfer of the impact energy onto the AT – TUBESPILE™

Ready-For-Use AT – TUBESPILE™

Specifications SI Units

Steel Grade [1]	Modulus of Elasticity	Yield Strength	Outer Diameter [2]	Wall Thickness	Weight	Standard Tube Length	Cross Section	Moment of Inertia	Section Modulus	Maximum Moment (Elastic)
[–]	[N/mm²]	[N/mm²]	[mm]	[mm]	[kg/m]	[m]	[cm²]	[cm⁴]	[cm³]	[kN·m]
S235	210 000	235	51	3,2	3,8	3,0 / 3,5 / 4,0 / 4,5	4,8	13,8	5,4	1,3
				4,5	3,8		6,6	17,9	7,0	1,6
S355 or E355		355		3,2	5,2		4,8	13,8	5,4	1,9
				4,5	5,2		6,6	17,9	7,0	2,5

Specifications US Customary Units

Steel Grade [1]	Modulus of Elasticity	Yield Strength	Outer Diameter [2]	Wall Thickness	Weight	Standard Tube Length	Cross Section	Moment of Inertia	Section Modulus	Maximum Moment (Elastic)
[–]	[ksi]	[ksi]	[in]	[in]	[lb/ft]	[ft]	[in²]	[in⁴]	[in³]	[lbf·ft]
3)	30 500	≥ 35	2,0	0,13	2,53	9,8 / 11,5 / 13,1 / 14,8	0,74	0,33	0,33	960
				0,18	3,47		1,02	0,43	0,43	1 180
4)		≥ 50		0,13	2,53		0,74	0,33	0,33	1 400
				0,18	3,47		1,02	0,43	0,43	1 840

1) Steel grade S235 and S355 according to EN 10025-2 or E355 according to EN 10296-1.

2) Deviating structural properties are available upon request.

3) Reference steel grade: carbon steel with a minimum yield strength of 35 [ksi].

4) Reference steel grade: carbon steel with a minimum yield strength of 51,5 [ksi].

Technical Features

- Self-drilling installation permits application in all ground types
- Different drill bits for various ground conditions
- Cased installation enables proper installation in poor ground even with unstable borehole walls
- Self-drilling installation ensures proper installation even in frequently changing ground conditions
- High heading accuracy of the spile drills thanks to the guidance of the spile tube
- No annular gap and therefore no settlements or ground loosening during installation
- Back-flushing inside the spile tube features least possible influence of the flushing water on ground properties
- Optionally available with holes for drainage or injection purposes
- Recording and control of the injection through an injection flow-pressure meter

Installation Procedure

1. Attachment of the AT – TUBESPILE™ spile tube and single-use drill bit onto the POWER SET drill rod, connection of the adapter and the rock drill.
2. Rotary-percussive self-drilling installation with a single-use drill bit; back-flushing of the cuttings through the annulus between drill rod and spile tube.
3. Completion of installation after the final drilling depth has been reached.
4. Retraction of the POWER SET drill rod from the installed AT – TUBESPILE™; the single-use drill bit remains inside the borehole.

Tubular and Rebar

Introduction

Tubular spiles and rebar spiles are universally applicable for pre-support measures. They can be installed into predrilled, stable boreholes in jointed rock mass and cohesive soil as well as rammed into soft, homogeneous ground.

Main Advantages

- Practice-proven spile systems
- Secure and simple installation
- Universally applicable
- Installation using conventional drilling machines
- Tubular spiles: optionally also available as injection spile

System Description

Tubular spiles consist of a steel tube, which is optionally provided with a welded ram top. Rebar spiles consist of smooth or ribbed steel bars that are pointed on one side. The installation is carried out with conventional drilling machines. Both spile types are either installed into pre-drilled spile holes or rammed into the ground. Pre-drilled spiles are used for jointed rock mass and cohesive soil as pre-support against falling rock mass, whereas ram spiles are applied in homogenous, soft ground.

By ramming, the stress situation is preserved, and an optimum initial condition for arching between the spiles is achieved. Following installation, the load of the ground is transferred to the bearings by the spiles. Those bearings are the ground ahead of the face, and the support arch in the already supported excavation area (primary lining).

Technical Features Tubular Spiles

- Simple and uncomplicated installation into pre-drilled boreholes
- Tubular ram spiles with steel point are available upon request
- Ground preserving installation by ramming – the original stress condition remains
- Ramming displaces the ground and allows for optimum load carrying characteristics at a later stage
- Installation is possible above as well as through the support arch
- High section modulus in relation to the weight
- Also available as injection spile with injection holes for ground improvement

Installation Procedure Tubular Spiles

- Installation into pre-drilled spile holes
  - Pre-drilling of spile holes through or above the support arch
  - Insertion of tubular spiles
- Installation as tubular ram spile
  - Ramming of tubular spiles through or over the support arch
  - Ram adapters available upon request

Specifications Tubular Spiles

Characteristic Value / Type [1]	Unit	38 x 4,0	51 x 3,2	51 x 4,5
Actual external diameter	[mm]	38	51	
	[in]	1,5	2,0	
Wall thickness	[mm]	4,0	3,2	4,5
	[in]	0,16	0,13	0,18
Delivery lengths [2]	[m]	3,0 / 4,0 / 6,0		
	[ft]	9,8 / 13,1 / 19,7		
Modulus of elasticity	[N/mm²]	210 000		
	[ksi]	30 450		
Moment of inertia	[cm⁴]	6,3	13,8	17,9
	[in⁴]	0,15	0,33	0,43

1) Minimum steel grade S235 (EN 10025-2). Alternatively, a carbon steel with a minimum yield strength of 35 [ksi] is required.

2) Off-size lengths and optional injection holes are available upon request.

Technical Features Rebar Spiles

- Simple and uncomplicated installation into pre-drilled spile holes
- Grouted annular gaps improve load transfer to the ground
- Ramming is an installation method which retains the original stress condition
- The ground is displaced by ramming; this permits optimum conditions for subsequent load carrying
- Installation is possible above as well as through support arches

Installation Procedure Rebar Spiles

- Installation into pre-drilled spile holes
  - Pre-drilling of the spile holes through or above the support arch
  - Filling of the spile holes with grout (only for grouted installation)
  - Installation of the rebar spile
- Installation as rebar ram spile
  - Ramming of the rebar spiles through or above the support arch

Specifications Rebar Spiles

- Spiles from smooth or ribbed concrete steel
- Minimum steel grade B 500 B (OENORM B 4700 or DIN 488-1) or grade 75 (ASTM A615)
- Bar diameters 20 [mm] to 36 [mm] or #6 to #11
- Delivery lengths 3 [m] to 6 [m] or 9,8 [ft] to 19,7 [ft]
- Pointed on one side
- Deviating lengths and unpointed rebar spiles are available upon request

Forepoling Boards

Introduction

Forepoling boards are used for laminar-active pre-support, which is particularly suitable for unstable, non-cohesive ground. This support is rammed into the ground using hydraulic drifters.

Main Advantages

- Installation using conventional drilling machines
- Secure and simple installation
- Closed support at the open span
- Ramming minimizes drive-induced ground stress relaxation

System Description

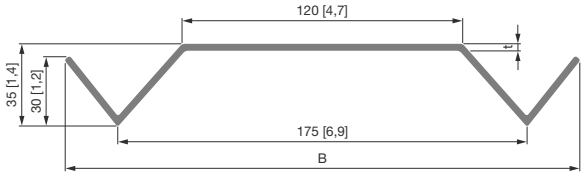
Forepoling boards are rammed above the support arch in a single step with conventional drill booms via a ram shoe. They are either installed with an overlap or with a gap when the ground shows little cohesion.

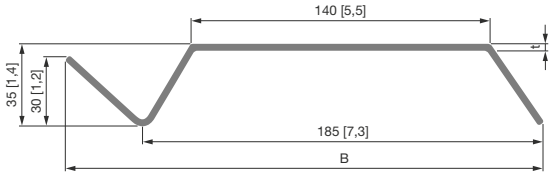
- Steel plate with one or two longitudinal seams
  - Plate thickness: 3 - 6 [mm] (1/8 - 15/64 [in])
  - Length: 1,25 - 3,0 [m] (4,1 - 9,8 [ft])
  - Width: approx. 220 [mm] (8 21/32 [in])
- Forepoling board template
  - Different versions available upon request
- Forepoling boards with deviating structural properties are available upon request

Technical Features

- Ramming with hydraulic rock drills
- Secure and simple installation
- Ramming prevents settlement and stress release ahead of the excavation

Schematic Drawing Type A and Type B





Specifications

SI Units

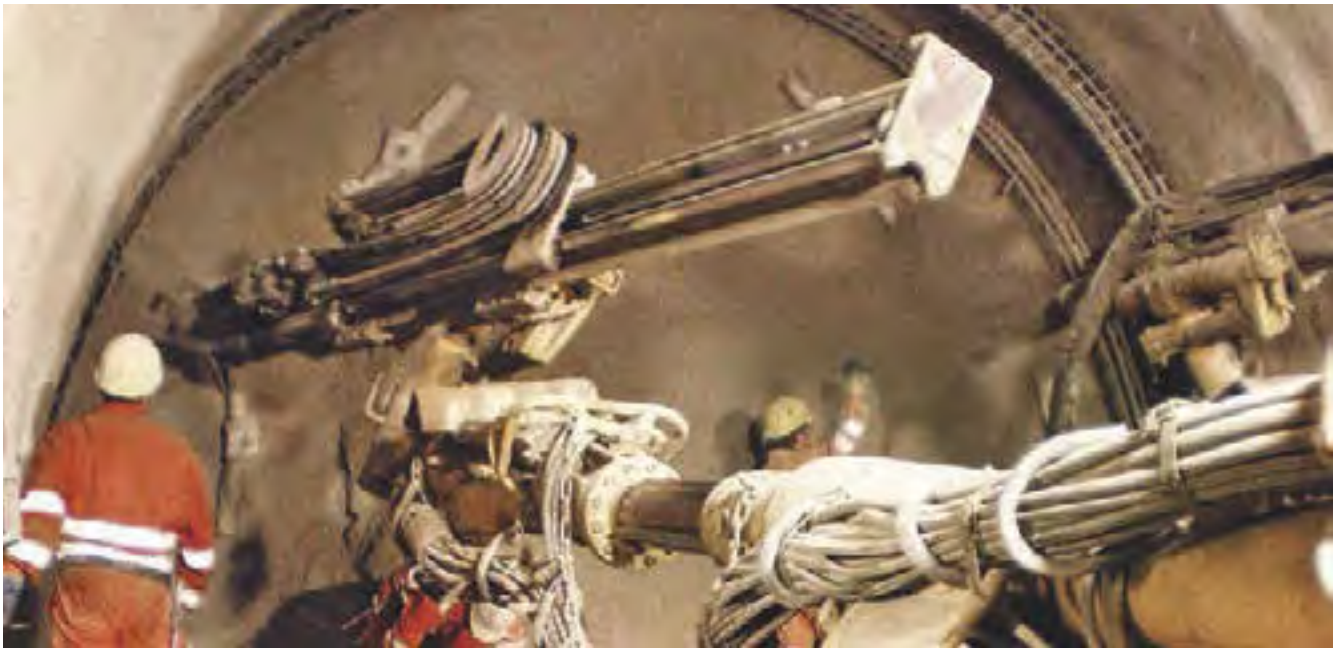
Characteristics	Symbol	Unit	A3 / B3					A4 / B4					A5 / B5					A6 / B6				
Thickness	t	[mm]	3					4					5					6				
Length [1]	L	[m]	1,25	1,50	2,00	2,50	3,00	1,25	1,50	2,00	2,50	3,00	1,25	1,50	2,00	2,50	3,00	1,25	1,50	2,00	2,50	3,00
Width [2]	B	[mm]	220					220					220					220				
Weight	m	[kg/m]	6					8					10					12				
Weight per piece	m_{Pcs}	[kg]	7,5	9,0	12,0	15,0	18,0	10,0	12,0	16,0	20,0	24,0	12,5	15,0	20,0	25,0	30,0	15,0	18,0	24,0	30,0	36,0
Section modulus	W_x	[cm^3]	8,9					10,6					12,2					13,8				

US Customary Units

Characteristics	Symbol	Unit	A3 / B3					A4 / B4					A5 / B5					A6 / B6				
Thickness	t	[in]	0,12					0,16					0,20					0,24				
Length [1]	L	[ft]	4,1	4,9	6,6	8,2	9,8	4,1	4,9	6,6	8,2	9,8	4,1	4,9	6,6	8,2	9,8	4,1	4,9	6,6	8,2	9,8
Width [2]	B	[in]	8,7					8,7					8,7					8,7				
Weight	m	[lb/ft]	4,0					5,4					6,7					8,1				
Weight per piece	m_{Pcs}	[lb]	17	20	26	33	40	22	26	35	44	53	28	33	44	55	66	33	40	53	66	79
Section modulus	W_x	[in^3]	0,54					0,65					0,74					0,84				

1) Special lengths are available upon request.

2) Reference width including overlapping: 5,7 pieces per [m] or 1,7 pieces per [ft].



AT – Pipe Umbrella

Introduction

The AT – Pipe Umbrella System is a pre-support measure used in weak ground conditions in conventional as well as mechanized Tunneling.

Long forepoling using the pipe umbrella or canopy method is typically applied to increase safety and stability in the working area of standard advance operations, portals, and for re-excavating collapsed sections.

Another application is ground improvement and waterproofing in combination with all tunnel construction methods.

Pipe umbrella pipes – installed into the ground prior to excavation – increase the stability in the working area by transferring loads in the longitudinal direction and decrease excavation induced deformations. DSI Underground has developed a superior pipe connection type, which allows the reduction of installation cycle times while increasing the load-bearing capacity.

State-of-the art pipe umbrella support systems are installed self-drilling where the casing provides an immediate support of the borehole, compared to outdated pre-drilling systems where borehole drilling and pipe installation takes place in two different working steps.

Fully mechanized installation is becoming a mandatory safety standard in the global Tunneling business.

DSI Underground is the leading system supplier in the development and application of safe and efficient pipe umbrella installation technology.

Main Advantages

- Supreme safety due to fully mechanized installation
- Efficient self-drilling installation technology
- The fastest pipe umbrella system on the market
- Installation with conventional drilling machines
- Implementation of pipe umbrella drilling with on-site personnel
- Reliable and robust system components
- Piecewise pipe installation allows flexible lengths
- Simple application in confined space
- Superior load-bearing capacity of innovative pipe couplings

System Components

Consumables

- Starter unit with drill bit
- Pipe umbrella pipes
- Injection valves

Multiple-Use Accessories

- Drill bit adapter
- Drill steel
- Grouting packer

Pipe Umbrella Design

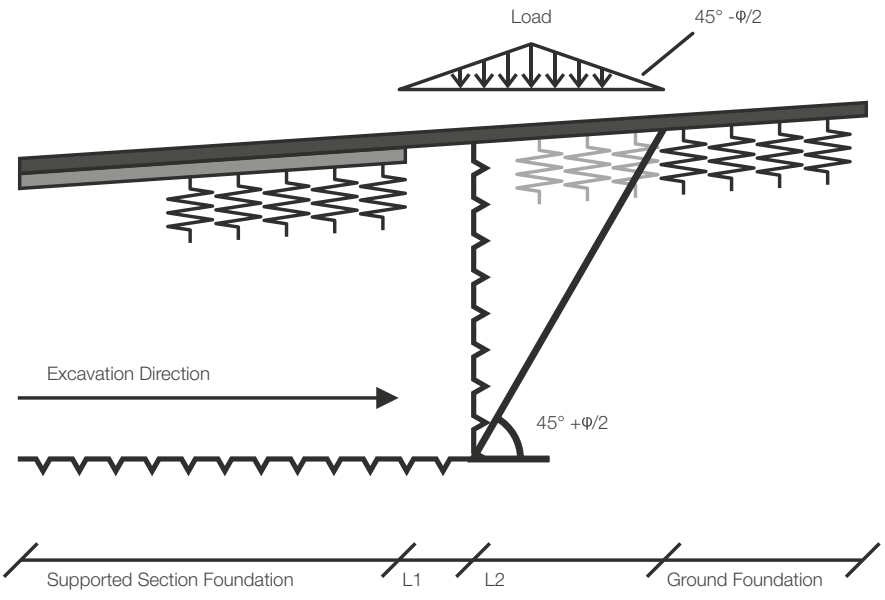
Support Effects

Pipe umbrella support systems with a typical installation length in the range of 12 [m] to 18 [m] (39,4 [ft] to 59,1 [ft]) are considered to be a long forepoling system. From a design perspective, supporting measures can be divided into three different effects:

- Subdivision of the unsupported zone in the open span of the working area
- Radial supporting effect
- Longitudinal supporting effect

Their interaction results in the support of the working area and face region. Loads in this critical section are transferred by each single umbrella pipe in the longitudinal direction to its foundations – the ground ahead of excavation and the already installed primary lining.

Pipe umbrella pipes are primarily loaded by bending. Therefore, the relevant design parameter is the maximum elastic moment of the system. The benchmark criterion is the performance of the weakest link, which usually is the pipe connection.



Volkmann & Schubert (2010)

Design Criteria

There are two common design criteria for the load transfer of pipe umbrella pipes:

- Maximum elastic moment M_y of both the standard pipe and the pipe connection – pure elastic design
- Elastic moment M_y of the standard pipe in combination with the ultimate moment M_{ult} of the pipe connection – elastic-plastic design

For both criteria, parameters relevant for design (M_y and M_{ult}) are product specific and must be verified by adequate certificates from the manufacturer before installation.

In case plastic material reserves of steel are activated by plastic joints in the pipe connection area, a safety factor of at least 1,3 to the tested value M_{ult} is recommended:

$M_{ult,\ pipe\ connection} \geq 1{,}3\ M_{y,\ standard\ pipe}$

This allows an elastic calculation and dimensioning of standard pipe umbrella pipes featuring state-of-the-art pipe connections without any further reduction of the load-bearing capacity.

Pipe Connection Types

Standard Threaded Connection

For a standard threaded connection, outside and inside threads are cut into both ends of each pipe umbrella pipe. This connection type reduces the cross section of the pipe in the threaded area. This way, the section modulus is decreased as well. The internal pipe diameter in the connection area stays constant.

Besides the geometrical conditions of the thread, the overall quality of threaded pipes is a concern for the load-bearing capacity. In general, calibrated pipes reach a higher resistance against bending than non-calibrated ones.

Squeezed Connection

A squeezed connection consists of a prefabricated reduced male pipe end, which is force-fitted with its female counter piece using a hydraulic clamping cylinder. In the coupling area, the cross section stays constant and the section modulus is decreased. The internal pipe diameter in the connection area is reduced.

This pipe connection type can be recommended where a pipe umbrella is installed because of its static load-bearing capacity.

Squeezing Unit

- Application in combination with default drilling machines
- Easy to handle and remote-controlled
- Safe and rapid pipe connection
- Hydraulically driven

Nipple Coupling

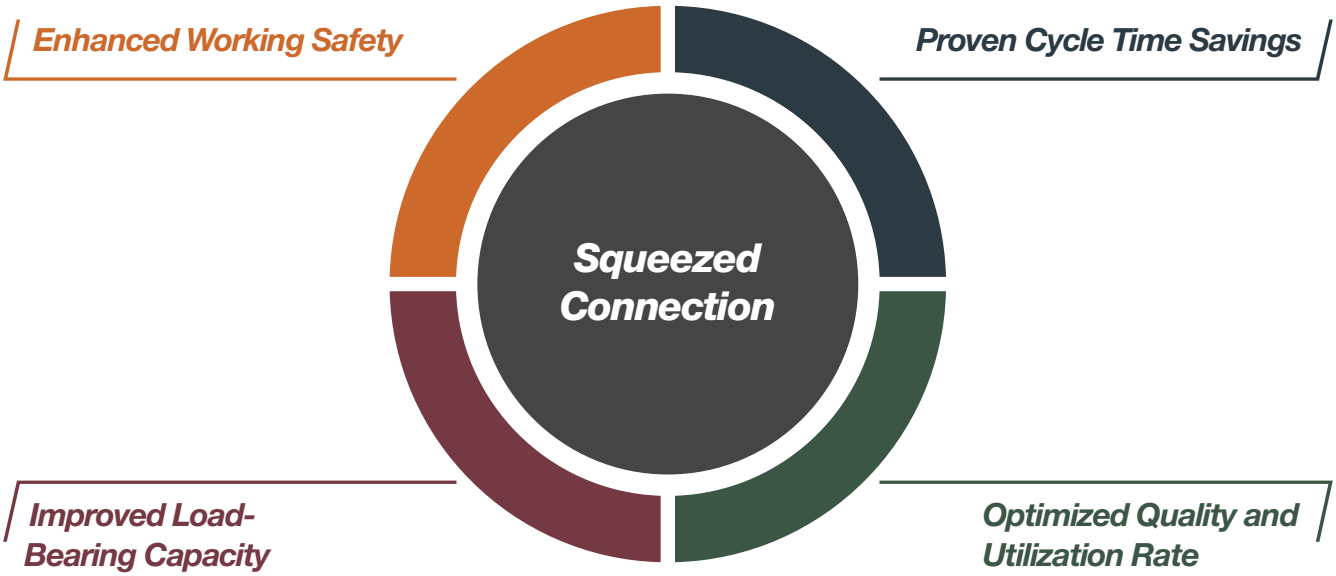
Nipple couplings consist of an additional threaded steel nipple that is pressed and welded into both ends of the pipe umbrella pipes. This connection type ensures that the second moment of inertia of the coupling is not lower than the second moment of inertia of the default pipe. The internal pipe diameter in the connection area is reduced.

This pipe connection type can be recommended for advances where enhanced static load-bearing capacity is required and settlement limitations are part of the design.

Comparison Pipe Connections

Criterion	Standard Threaded Connection	Squeezed Connection	Nipple Coupling
Connection type	Outside and inside thread is cut into the ends of the pipe umbrella pipes	Reduced pipe end force-fitted with its counter piece	Threaded steel nipple, pressed and welded into both ends of pipe umbrella pipes
Static influence	Significant reduction of pipe cross-section and section modulus in the thread connection area	Constant cross section and reduced section modulus in the coupling area	Second moment of inertia at the coupling is not lower than the second moment of inertia of the standard pipe
Elastic behavior	Stiffness and strength are considerably lower than those of standard pipes	Reduction of the stiffness against bending in the connection area	Stiffness and strength are adequate to standard pipes
Ultimate behavior	Rupture load of connections can be lower than elastic load of standard pipes	Ultimate load is higher than the elastic design load of a standard pipe (> 1,5)	Higher rupture load of connections compared to standard pipes
Recommended usage	Installation of measurement instrumentation or ground improving injections	Pipe umbrella with a designed static load-bearing capacity	Projects where settlement limitations are part of the design

Groundbreaking Technology



Enhanced Working Safety

- Remote-controlled operation allows a safe pipe connection
- Reduction of physical labor required
- No manual work during the pipe connecting working step
- Integrated drill rod wrench allows safe manipulation of drill steel

Conventional (Threaded) Installation	Squeezed Connection
Manual connection of pipe umbrella pipes: chain pipe wrench	Remote-controlled pipe connection using a hydraulic cylinder assembly
Manual connection and disconnection of drill rods: drill rod wrench	Centralized connection and remote-controlled drill steel disconnection
Direct exposure of personnel to moving drilling tools and hydraulic drifter	Limitation of personnel exposed to the operation range of the hydraulic hammer

Proven Cycle Time Savings

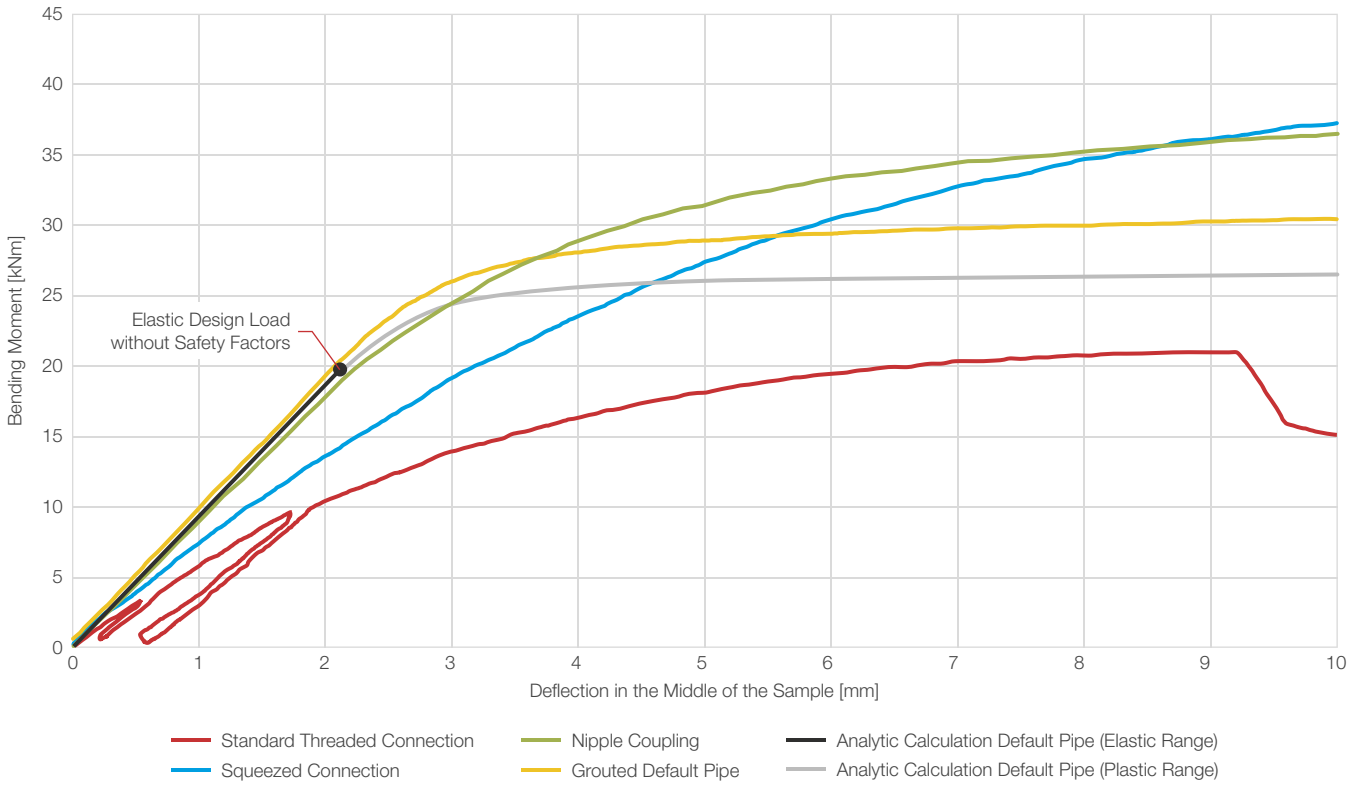
- Faster connection process than for standard threads
- Elimination of delays due to jammed or damaged pipes
- Total time savings of approx. 3 hours for an exemplary pipe umbrella: 15 pipe umbrella drills, each 18 [m] (59,1 [ft]) long
- Experience: 5% difficult threaded connections (outliers), which require additional handling time

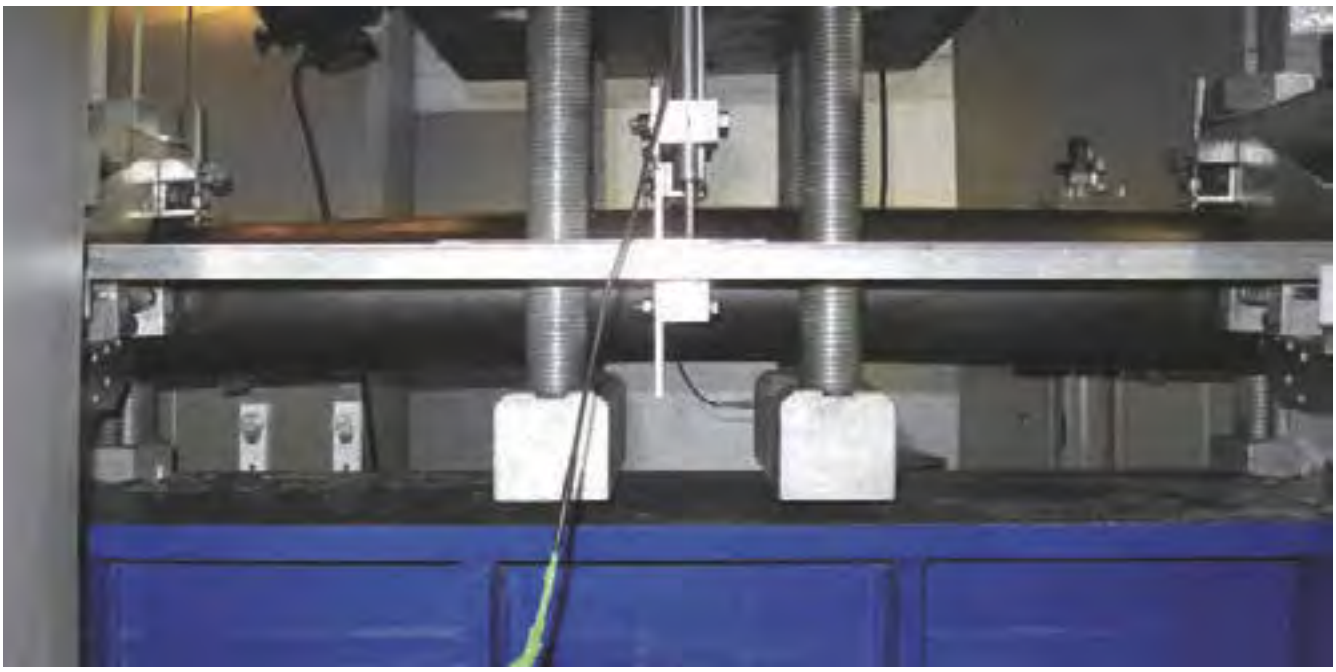
Parameter	Unit	Standard Threaded Connection	Squeezed Connection	Time Savings
No. of pipes	[1]	15		—
Single pipe length	[m]	3		—
Pipe umbrella length	[m]	18		—
No. of connections	[1]	75		—
Single connecting time	[min]	3,5	1,5	2
Single delay time	[min]	10	0	10
No. of difficult connections	[1]	5%	0%	—
Total connecting time	[min]	262,5	112,5	150
Total delay time	[min]	37,5	0	37,5
Sum	**[min]**	**300**	**112,5**	**187,5**

Improved Load-Bearing Capacity

- Load-transfer based design criteria: elastic and plastic moments of the pipe connection
- Design criterion 1: maximum elastic moment M_y of the pipe connection is improved
- Design criterion 2: significantly higher ultimate moment M_{ult} of the pipe connection than the elastic design load (standard pipe)
- Example: comparison of pipe couplings AT – 114,3 x 6,3 [mm], steel grade S/E 355 (355 [N/mm²] or 51,5 [ksi])

Bending Tests: Comparison Pipe Couplings AT – 114,3 x 6,3 [mm]





Optimized Quality

Standard Threaded Connection	Squeezed Connection
Significant difference between default and calibrated pipes provided by DSI Underground	Error-free system
Sufficient thread strength extremely dependent on the quality of the threading	Verified quality for every single pipe connection
Additional impacts on the threads during transport and installation	Robust system and high-strength pipe connection designed for the special demands of the construction industry

Utilization Rate

– Performance-based design approach
- Enhanced load-bearing capacity allows reduction of pipe wall thickness compared to threaded connections
- Significant material savings potential with simultaneous increase in performance
- Lower transport weight increases efficiency of logistics
- Easier handling procedures due to decreased weight of single umbrella pipes
- Exemplary parameter study: AT – 139 Pipe Umbrella System with different connection types and wall thicknesses

Parameter	Unit	Standard Threaded Connection (Calibrated Pipes)		Squeezed Connection	Change Threaded to Squeezed Connection
Pipe dimensions	[mm]	139,7 x 8,0	139,7 x 10	139,7 x 6,3	–
Unit weight	[kg/m]	26,0	32,0	20,7	-20% / -35%
Max. elastic moment M_y	[kNm]	14,1	18,4	20,4	+45% / +11%

Specifications SI Units

System [1]	Steel Grade [2]	Modulus of Elasticity	Yield Strength	Outer Diameter	Wall Thickness	Weight	Section Modulus	Second Moment of Area
Type	[–]	[N/mm²]	[N/mm²]	[mm]	[mm]	[kg/m]	[cm³]	[cm⁴]
AT – 76	E355 or S355	210 000	355	76,1	6,3	10,8	22	85
AT – 89				88,9	5,0	10,4	26	116
				88,9	**6,3**	**12,8**	**32**	**140**
				88,9	8,0	16,0	38	168
AT – 114				114,3	5,0	13,5	45	257
				114,3	**6,3**	**16,8**	**55**	**313**
				114,3	8,0	21,0	66	379
AT – 139				139,7	5,0	16,6	69	481
				139,7	**6,3**	**20,7**	**84**	**589**
				139,7	**8,0**	**26,0**	**103**	**720**
				139,7	10,0	32,0	123	862
AT – 168				168,3	10,0	39,0	186	1 564
				168,3	12,5	48,0	222	1 868
				168,3	16,0	60,1	267	2 244

System [1]	Outer Diameter	Wall Thickness	Maximum Elastic Moment M_y [3]				Ultimate (Plastic) Moment M_{ult} [3]
			Standard Pipe	Nipple Couplings	Squeezed Connection	Threaded Connection (Calibrated Pipes)	Squeezed Connection [4]
Type	[mm]	[mm]	[kNm]	[kNm]	[kNm]	[kNm]	[kNm]
AT – 76	76,1	6,3	7,9	N/A	N/A	2,9	N/A
AT – 89	88,9	5,0	9,3	N/A	5,9	N/A	15,4
	88,9	**6,3**	**11,2**	**N/A**	**6,5**	**4,1**	**21,7**
	88,9	8,0	13,4	N/A	N/A	5,4	N/A
AT – 114	114,3	5,0	16,0	16,0	10,5	N/A	29,3
	114,3	**6,3**	**19,4**	**19,3**	**12,1**	**6,9**	**33,1**
	114,3	8,0	23,6	19,3	13,2	9,3	41,8
AT – 139	139,7	5,0	24,4	24,4	17,5	N/A	41,0
	139,7	**6,3**	**29,9**	**29,9**	**20,4**	**10,4**	**50,0**
	139,7	**8,0**	**36,6**	**36,6**	**23,3**	**14,1**	**64,0**
	139,7	10,0	43,8	38,8	N/A	18,4	N/A
AT – 168	168,3	10,0	66,0	66,0	N/A	26,0	N/A
	168,3	12,5	78,8	69,7	N/A	33,5	N/A
	168,3	16,0	94,7	N/A	N/A	43,2	N/A

1) Deviating structural properties are available upon request. Commonly used systems are bold marked. Non-applicable combinations (system and connection type) are indicated by “N/A”.

2) Steel grade S355 according to EN 10025-2 or E355 according to EN 10296-1. Alternatively, a carbon steel with a minimum yield strength of 355 [N/mm²] is required.

3) Values for M_y and M_{ult} are product-specific and verified by DSI Underground inspection certificates. Laboratory test reports are available upon request.

4) 95% fractile values determined from results of laboratory bending tests performed with samples in accordance with DSI Underground Austria test specifications.

Specifications US Customary Units

System [1]	Steel Grade [2]	Modulus of Elasticity	Yield Strength	Outer Diameter	Wall Thickness	Weight	Section Modulus	Second Moment of Area
Type	[–]	[ksi]	[ksi]	[in]	[in]	[lb/ft]	[in³]	[in⁴]
AT – 76	E355 or S355	30 458	≥ 51,5	3,0	0,25	7,3	1,34	2,04
AT – 89				3,5	0,20	7,0	1,59	2,79
				3,5	**0,25**	**8,6**	**1,95**	**3,36**
				3,5	0,31	10,8	2,32	4,04
AT – 114				4,5	0,20	9,1	2,75	6,17
				4,5	**0,25**	**11,3**	**3,36**	**7,52**
				4,5	0,31	14,1	4,03	9,11
AT – 139				5,5	0,20	11,2	4,21	11,56
				5,5	**0,25**	**13,9**	**5,13**	**14,15**
				5,5	**0,31**	**17,5**	**6,29**	**17,30**
				5,5	0,39	21,5	7,51	20,71
AT – 168				6,6	0,39	26,2	11,35	37,58
				6,6	0,49	32,3	13,55	44,88
				6,6	0,63	40,4	16,29	53,91

System [1]	Outer Diameter	Wall Thickness	Maximum Elastic Moment M_y [3]				Ultimate (Plastic) Moment M_{ult} [3]
			Standard Pipe	Nipple Couplings	Squeezed Connection	Threaded Connection (Calibrated Pipes)	Squeezed Connection [4]
Type	[in]	[in]	[lbf·ft]	[lbf·ft]	[lbf·ft]	[lbf·ft]	[lbf·ft]
AT – 76	3,0	0,25	5,83	N/A	N/A	2,14	N/A
AT – 89	3,5	0,20	6,86	N/A	4,35	N/A	11 360
	3,5	**0,25**	**8,26**	**N/A**	**4,79**	**3,02**	**16 005**
	3,5	0,31	9,88	N/A	N/A	3,98	N/A
AT – 114	4,5	0,20	11,8	11,80	7,74	N/A	21 610
	4,5	**0,25**	**14,31**	**14,23**	**8,92**	**5,09**	**24 415**
	4,5	0,31	17,41	14,23	9,74	6,86	30 830
AT – 139	5,5	0,20	18,00	18	12,91	N/A	30 240
	5,5	**0,25**	**22,05**	**22,05**	**15,05**	**7,67**	**36 880**
	5,5	**0,31**	**26,99**	**26,99**	**17,19**	**10,40**	**47 205**
	5,5	0,39	32,31	28,62	N/A	13,57	N/A
AT – 168	6,6	0,39	48,68	48,68	N/A	19,18	N/A
	6,6	0,49	58,12	51,41	N/A	24,71	N/A
	6,6	0,63	69,85	N/A	N/A	31,86	N/A

1) Deviating structural properties are available upon request. Commonly used systems are bold marked. Non-applicable combinations (system and connection type) are indicated by "N/A".

2) Steel grade S355 according to EN 10025-2 or E355 according to EN 10296-1. Reference: carbon steel with a minimum yield strength of 51,5 [ksi].

3) Values for M_y and M_{ult} are product-specific and verified by DSI Underground inspection certificates. Laboratory test reports are available upon request.

4) 95% fractile values determined from results of laboratory bending tests performed with samples in accordance with DSI Underground Austria test specifications.

Self-Drilling Installation Technology

Installation Method

The AT – Pipe Umbrella System is installed:

- Self-drilling
- Piecewise
- With conventional drilling machines
- By hydraulic, rotary-percussive drilling

Cooling, flushing, and backflow of the cuttings takes place inside the casing pipes by using water or an air-water mist. Self-drilling installation features the smallest possible stress relaxation due to an immediate support of the borehole wall during installation and an accurate installation due to a minimized annular gap.

The length of piecewise installed pipe umbrella pipes can be adjusted according to project or machinery requirements.

Starter Unit

One important factor in the success of the AT – Pipe Umbrella Support System is the starter unit:

- Single-use full face drill bits ensure the same quality for each drilling process
- Stable drilling direction due to stable drill bit orientation
- Simple connection and disconnection of the drill bit adapter
- Proven back-flushing of water inside umbrella pipes
- Loss or blocking of a drill bit is impossible – optimum pre-conditions for achieving the total drilling depth every time
- Starter unit (drill bit) bit can be adapted to given ground conditions

Installation Procedure Using the AT – Pipe Umbrella Automation Unit

1. For drilling, the starter unit with drill bit is assembled onto the drill boom together with the first extension tube, the adapter, and the drill rod.

2. Installation of the first extension tube.

3. The next drill rod with extension tube is connected to the previously installed pipe and the drilling process is continued. Reloading AT – Automation Unit (extension tube and drill rod).

4. The last step is to be repeated until the designed length of the AT – Pipe Umbrella has been installed. Followed by removal of drill bit adapter and drill steel.

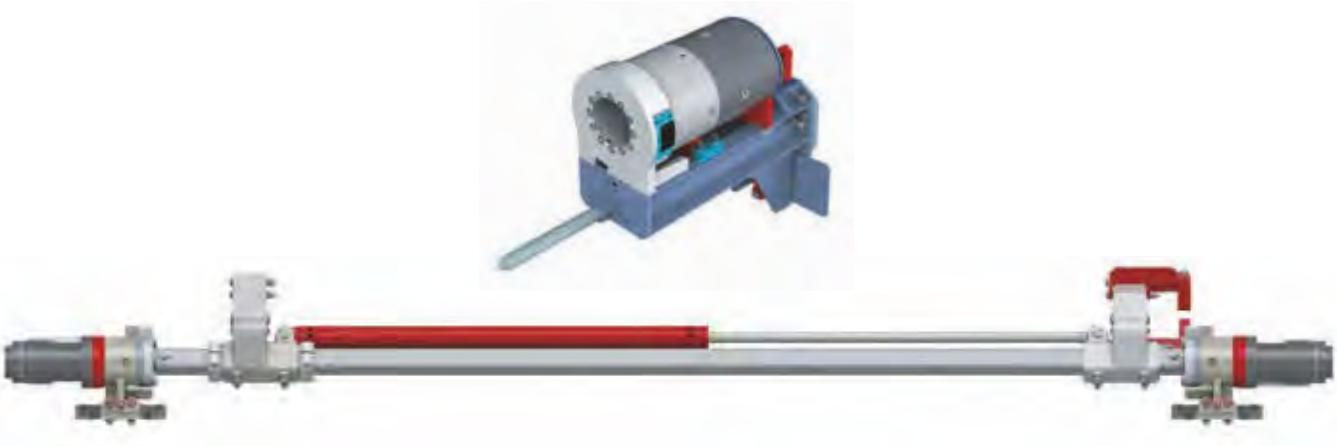
AT – Pipe Umbrella Automation Unit

Main Advantages

- Compatible with every standard drill jumbo
- Shorter manipulation times due to exact and mechanized feeding
- Faster construction of a pipe umbrella support system
- Higher occupational safety
- No handling in the vicinity of moving parts of the drilling machine
- Simple re-charging of extension pipes via a loading basket
- Remote-controlled feeding
- Less manpower required
- Optimum utilization of the working space
- Smaller saw-tooth shaped profile and thereby less excavation volume

Mechanized Installation – Selection of the Required Degree

Installation Mode / Characteristics	Pipe Connection Type	Degree of Mechanization	Mechanized Working Steps
Conventional installation	Threaded	0%	N/A
Threading unit	Threaded	50%	Pipe connection, drill steel clamping (wrench)
Squeezing unit	Squeezed	50%	Pipe connection, drill steel clamping (wrench)
AT – Automation Unit	Threaded or Squeezed	100%	Pipe connection, drill steel clamping (wrench), drill steel connection, pipe, and drill steel feeding

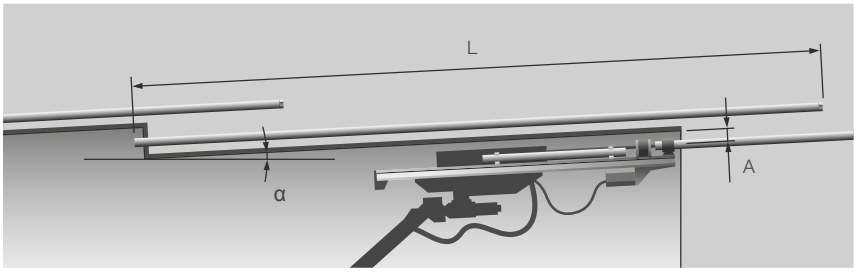


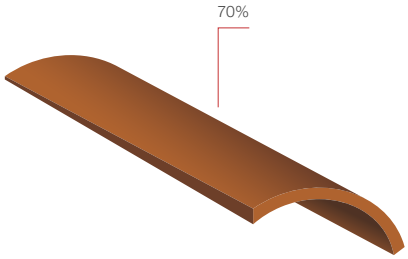
Comparison of Pipe Consumption and Over-Excavation

- Different pipe umbrella lengths, conventional, and mechanized installation
- Top heading excavation with 6 [m] (19,5 [ft]) radius and 1 [m] (3,3 [ft]) advance length
- AT – 114 Pipe Umbrella, axial pipe distance 500 [mm] (19,5 [in]), overlap 3,5 [m] (11,5 [ft])

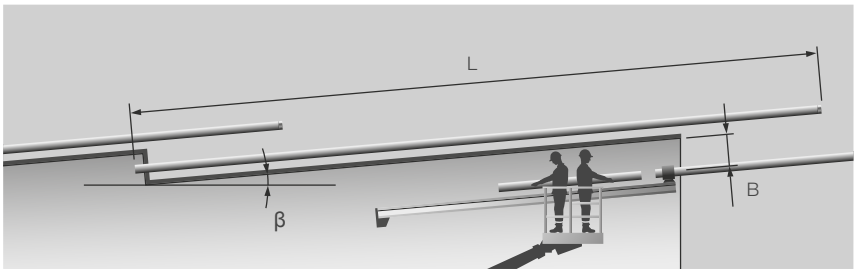
Pipe Umbrella Length L	Pipes per Umbrella	Excavation Steps per Umbrella	Pipes Installed per Umbrella	Pipes Installed per [m] Tunnel		Mechanized Installation				Conventional Installation			
						Head-Room A	Inclination α	Over-Excavation Sawtooth		Head-Room B	Inclination β	Over-Excavation Sawtooth	
[m]	[1]	[1]	[m]	[m/m]	[%]	[mm]	[°]	[m³]	[m³/m]	[mm]	[°]	[m³]	[m³/m]
12		8	360	45,0	100%		6,0	63,1	7,9		8,1	89,2	11,2
15	30	11	450	40,9	91%	300	4,4	85,6	7,8	600	5,9	121,1	11,0
18		14	540	38,6	86%		3,5	108,1	7,7		4,7	153,0	10,9
[ft]	[1]	[1]	[ft]	[ft/ft]	[%]	[in]	[°]	[ft³]	[ft³/ft]	[in]	[°]	[ft³]	[ft³/ft]
39,4		8	1 181	147,6	100%		6,0	2 228	279		8,1	3 150	394
49,2	30	11	1 476	134,2	91%	11,8	4,4	3 023	275	23,6	5,9	4 277	389
59,1		14	1 772	126,5	86%		3,5	3 818	273		4,7	5 403	386

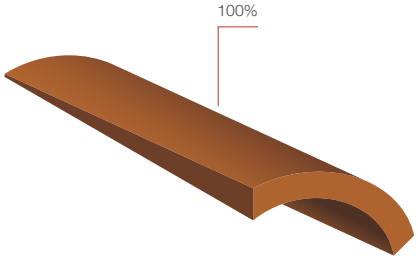
Mechanized Installation



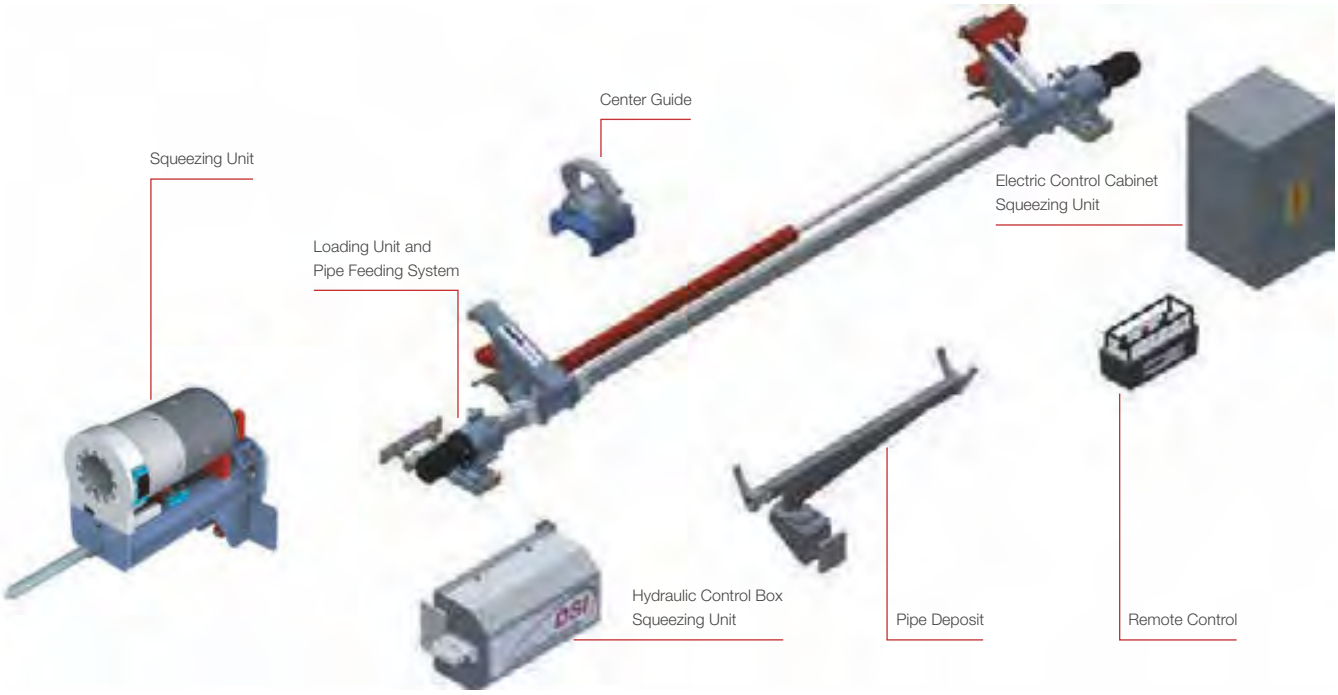


Conventional Installation





Assembly Groups – Squeezing Unit



Specifications SI Units

Characteristics / Assembly Group	Dimensions	Weight
[–]	(L x W x H) [mm]	[kg]
Pipe deposit	1 040 x 230 x 350	28
Squeezing unit	1 165 x 380 x 750	200
Loading unit and pipe feeding system	3 650 x 460/780 x 430/570	160
Center guide	155 x 260 x 230	12
Hydraulic control box squeezing unit	550 x 275 x 345	60
Electric control cabinet squeezing unit	395 x 615 x 355	35
Remote control	250 x 140 x 180	2,3

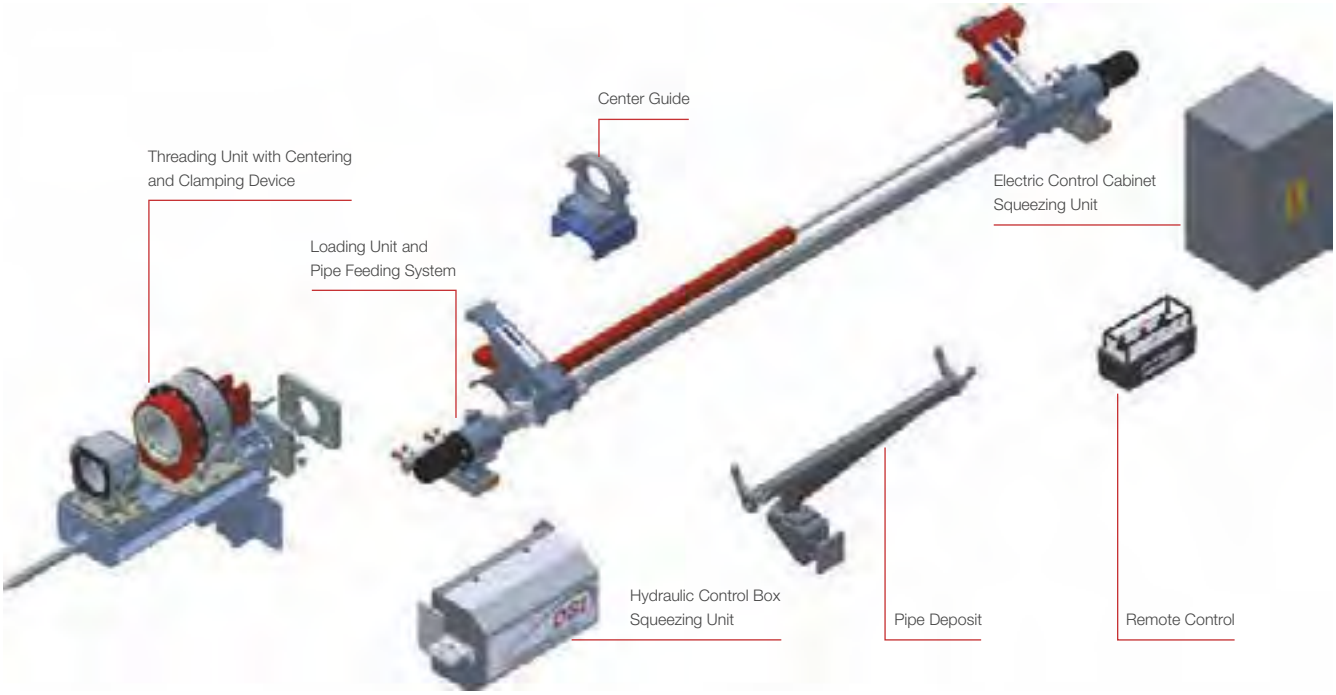
Characteristics	Unit	Value	Remarks
Total weight (gross)	[kg]	500 - 520	Deviations possible, depending on the type
Electric supply	[V]	24	DC
Hydraulic supply	[L/min]	20 - 25	At approx. 200 [bar]

Specifications US Customary Units

Characteristics / Assembly Group	Dimensions	Weight
[–]	(L x W x H) [in]	[lb]
Pipe deposit	40,9 x 9,1 x 13,8	62
Squeezing unit	45,9 x 15,0 x 29,5	441
Loading unit and pipe feeding system	143,7 x 18,1/30,7 x 16,9/22,4	353
Center guide	6,1 x 10,2 x 9,1	27
Hydraulic control box squeezing unit	21,6 x 10,8 x 13,8	133
Electric control cabinet squeezing unit	15,6 x 24,2 x 14,0	77
Remote control	9,8 x 5,5 x 7,1	5

Characteristics	Unit	Value	Remarks
Total weight (gross)	[lb]	1 100 - 1 150	Deviations possible, depending on the type
Electric supply	[V]	24	DC
Hydraulic supply	[gal/min]	5,3 - 6,6	At approx. 2 900 [psi]

Assembly Groups – Threading Unit



Specifications SI Units

Characteristics / Assembly Group	Dimensions	Weight
[–]	(L x W x H) [mm]	[kg]
Pipe deposit	1 040 x 230 x 350	28
Threading unit with centering and clamping device	1 165 x 370 x 740	160
Loading unit and pipe feeding system	3 650 x 460/780 x 430/570	160
Center guide	155 x 260 x 230	12
Hydraulic control box threading unit	550 x 275 x 345	60
Electric control cabinet threading unit	395 x 615 x 355	35
Remote control	250 x 140 x 180	2,3

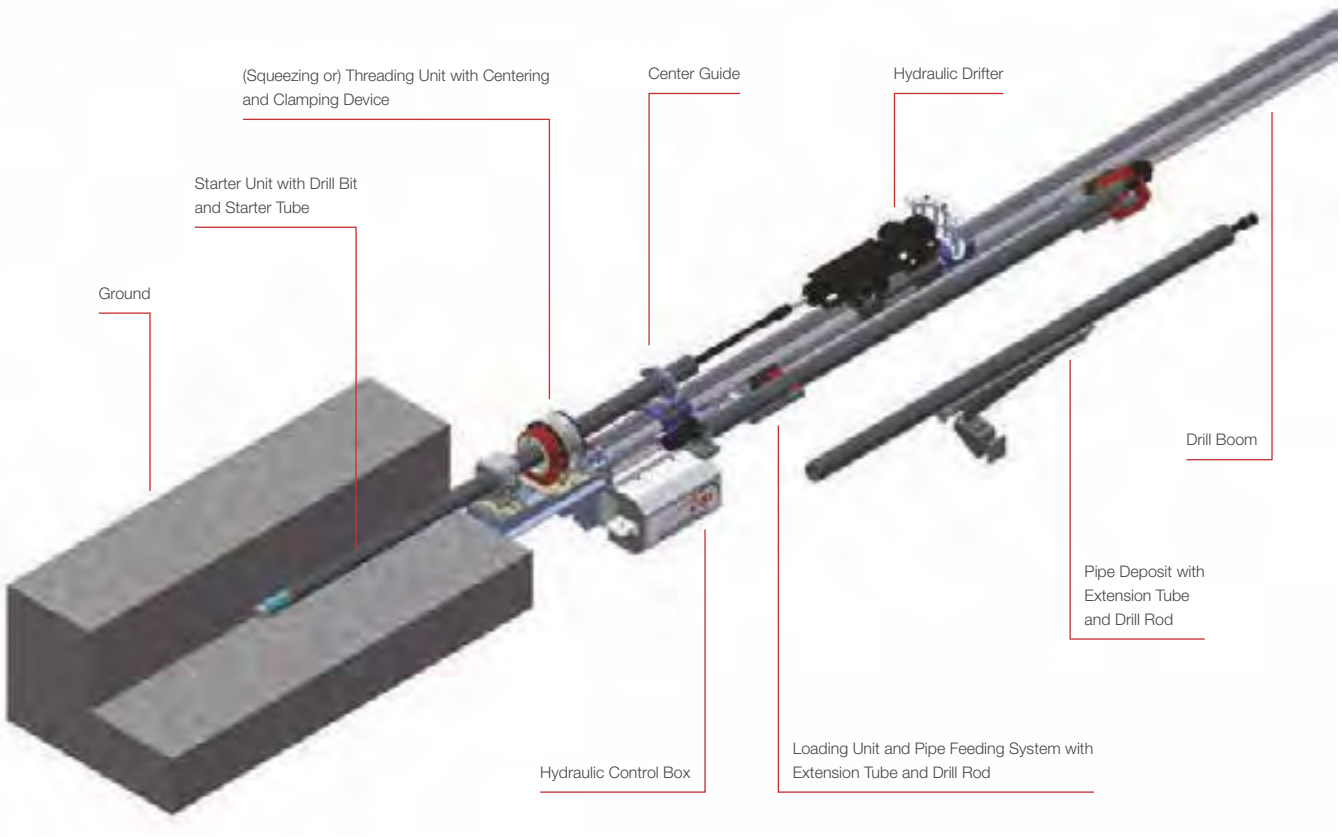
Characteristics	Unit	Value	Remarks
Total weight (gross)	[kg]	460 - 490	Deviations possible, depending on the type
Electric supply	[V]	24	DC
Hydraulic supply	[L/min]	15 - 20	At approx. 170 [bar]

Specifications US Customary Units

Characteristics / Assembly Group	Dimensions	Weight
[–]	(L x W x H) [in]	[lb]
Pipe deposit	40,9 x 9,1 x 13,8	62
Threading unit with centering and clamping device	45,9 x 14,6 x 29,1	353
Loading unit and pipe feeding system	143,7 x 18,1/30,7 x 16,9/22,4	353
Center guide	6,1 x 10,2 x 9,1	27
Hydraulic control box threading unit	21,6 x 10,8 x 13,8	133
Electric control cabinet threading unit	15,6 x 24,2 x 14,0	77
Remote control	9,8 x 5,5 x 7,1	5

Characteristics	Unit	Value	Remarks
Total weight (gross)	[lb]	1 010 - 1 080	Deviations possible, depending on the type
Electric supply	[V]	24	DC
Hydraulic supply	[gal/min]	4,0 - 5,3	At approx. 2 500 [psi]

Mounted Assembly Groups

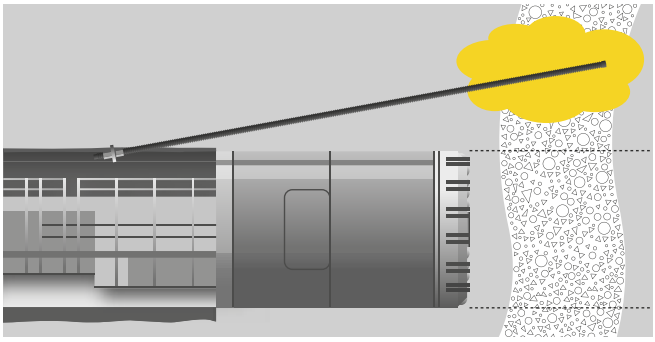


Accessories

1. Injection flow-pressure meter
2. Injection packer
3. Grout mixing pump
4. DSI Inject Systems
5. Fishing tab
6. Drill rod wrench
7. Chain pipe wrench
8. Online chain inclinometer measurements
9. Online fiber glass measurements
10. Rock drilling equipment: shank adapter, coupling, and coupling adapter

Mechanized Tunneling

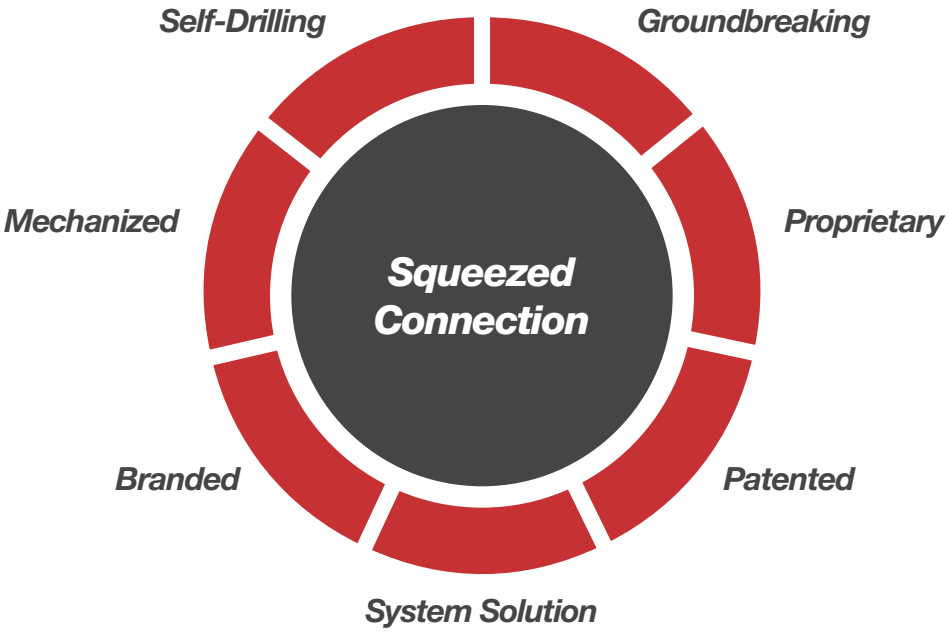
The AT – Pipe Umbrella Support System can be combined with fiberglass or PVC extension pipes for application in mechanized Tunneling.



References

- Volkmann, G.M. 2004: A Contribution to the Effect and Behavior of Pipe Roof Supports. In proceedings of the EUROCK 2004 & 53rd Geomechanics Colloquium
- Volkmann, G.M., & W. Schubert 2006. Optimization of excavation and support in pipe roof supported tunnel sections. In proceedings of the 32nd ITA-AITES World Tunneling Congress, Seoul, 2006, 404 ff
- Volkmann, G.M & W. Schubert 2006: Contribution to the Design of Tunnels with Pipe Roof Support. In Proc. of 4th Asian Rock Mechanics Symposium, ISRM International Symposium. eds. Leung C.F. & Zhou Y.X., ISBN 981-270-437-X World Scientific Publishing Co. Pte. Ltd., Singapore, 8th - 10th November 2006
- Volkmann, G.M. & W. Schubert 2007: "Geotechnical Model for Pipe Roof Supports in Tunneling." In proceedings of the 33rd ITA-AITES World Tunneling Congress, Underground Space – the 4th Dimension of Metropolises, Volume 1. eds. J. Bartak, I.Hrdina, G.Romancov, J. Zlamal, Prague, Czech Republic, 5-10 May 2007, Taylor & Francis Group, ISDN: 978-0- 415-40802. app. 755-760
- Volkmann, G.M. & W. Schubert, 2008: "Tender Document Specifications for Pipe Umbrella Installation Methods." In proceedings of the 34th ITA-A ITES World Tunneling Congress, Agra, India, 22-24 September 2008, pp. 285-293
- Volkmann G.M. & Schubert W. 2010: "A load and load transfer model for pipe umbrella support." In proceedings of EUROCK 2010, Rock Mechanics in Civil and Environmental Engineering – Zhao, Labiouse, Dudt & Mathier (eds), © 2010 Taylor & Francis Group, London, ISBN 978-0-415-58654-2, pp. 379-382
- Volkmann, G.M. 2013: "The AT – Casing System – more than a Pipe Umbrella System." In proceedings of the 12th International Conference Underground Construction Prague 2013. Czech Republic, Prague, 22–24 April 2013, ISBN: 978-80-260-3868-9
- Volkmann, G.M. 2014: "Development of State-of-the-Art Connection Types for Pipe Umbrella Support Systems." In proceedings of the 15th Australasian Tunneling Conference 2014, Sydney, Australia, 17-19 September 2014, pp. 333-338
- Volkmann, G.M., Moritz, B., Schneider, K.M., 2015: "Application of the Pipe Umbrella Support System at the Koralm Tunnel KAT 3." In Underground Design and Construction Conference 2015, Eds. G. Bridges, W.L. Siu & A. Dias, Hong Kong, China, 11-12 September 2015, The Institute of Materials, Minerals and Mining (Hong Kong Branch), ISBN 978-988-18778-8-8, pp. 313-321
- Volkmann, G.M. 2016: Advanced Pre-Support for Cross Passages. In proceedings of the TAI-Workshop Best Practices for Safe Cross Passage – Investigation, Design, and Construction. New Delhi, India, September 8-9, 2016
- Volkmann, G.M. 2017: "Function, Design, and Specifications for Pipe Umbrella Support Systems." Doctoral Thesis, Graz University of Technology, Department of Civil Engineering, Institute for Rock Mechanics and Tunneling, Graz, Austria
- Volkmann G.M. & D. Glantschnegg, 2017: "Optimization Potential Regarding Safety, Material, and Installation Time for Pipe Umbrella Installation Methods." In proceedings of the 16th Australasian Tunnelling Conference 2017, Challenging Underground Space: Bigger, Better, More, 30 October – 1 November 2017; Sydney, Australia

AT – Pipe Umbrella System at a Glance



AT – TUBESPILE™ Vacuum Lances

Introduction

The AT – TUBESPILE™ vacuum lance forms a part of the POWER SET product family. The system consists of an exterior steel tube with a PVC drainage tube inserted after drilling. The main field of application is the temporary or semi-temporary drainage of ground around the excavation geometry in Tunneling and civil engineering.

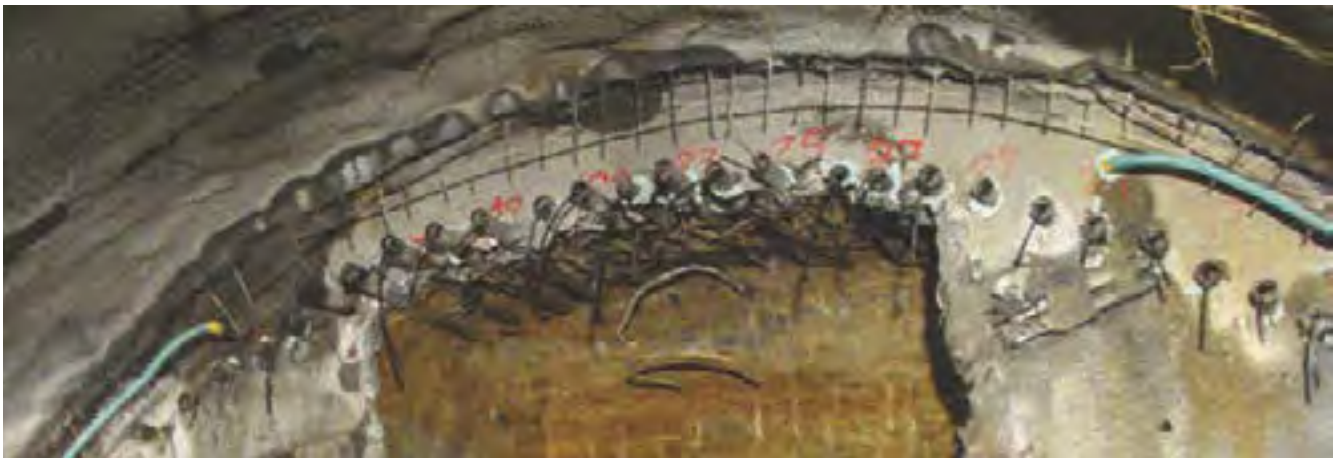
Main Advantages

- Installation using standard drilling machinery
- Simple and robust system components
- Secure and simple installation
- Drainage drilling and casing installation in one operational step
- Ground preserving, self-drilling installation

System Description

AT – TUBESPILE™ vacuum lances are installed rotary-percussive in one step using a conventional drill boom.
A drill rod inside the casing tube transfers the drilling energy onto the drill bit, which is available either as button drill bit with carbide inserts or hardened arc-shaped drill bit.

The AT – TUBESPILE™ with drainage openings is pushed with an adapter directly behind the drill bit. Cooling, flushing, and back-flushing of the borehole cuttings are carried out using water inside the casing tube. To finish the installation, a PVC filter pipe is inserted into the casing. In case of vacuum drainage, a drainage hose can be fastened onto the vacuum lance following installation.



System Components

- AT – TUBESPILE™ drill bit
  - Single-use drill bits Ø 52 [mm] (Ø 2 3/64 [in]) available as arch-shaped or button drill bit version
- AT – TUBESPILE™ vacuum lance
  - Ø 51 x 3,2 [mm] (Ø 2 x 1/8 [in]) with drainage openings and 2" connecting thread
- POWER SET drill rod
  - Special drill rod for high service life
- POWER SET coupling adapter
  - Controlled transfer of the impact energy onto the AT – TUBESPILE™ and the drill bit
- AT – TUBESPILE™ filter pipe
  - Customized slot opening width

Ready-For-Use AT – TUBESPILE™ Vacuum Lance

Specifications [1)]

System	Material	Outer Diameter		Wall Thickness		Weight		Standard Lengths	
[–]	[–]	[mm]	[in]	[mm]	[in]	[kg/m]	[lb/ft]	[m]	[ft]
AT – TUBESPILE™ with drainage openings	Steel [2)]	51	2,0	3,2	0,13	3,8	2,6	3 / 3,5 / 4 / 4,5	9,8 / 11,5 / 13,1 / 14,8
Filter pipe	PVC [3)]	44	1,7	3,5	0,14	1,6	1,1	3,0	9,8

1) Different dimensions are available upon request.

2) Steel grade ≥ S235 according to EN 10025-2 or reference steel grade 35 [ksi].

3) Slot opening width 0,6, 1,0, and 1,5 [mm] (1/32, 3/64, and 1/16 [in]); 3 slots around the whole pipe circumference.

Technical Features

- Self-drilling installation permits application in all ground conditions
- Number of drainage holes and filter slot size are adaptable
- Different drill bit types are available
- Cased installation allows proper installation even in frequently changing or poor ground conditions
- No annular gap and therefore no settlement or loosening during installation

Installation Procedure

1. Attachment of the AT – TUBESPILE™ vacuum lance and the AT – TUBESPILE™ single-use drill bit onto the POWER SET drill rod, connection of the POWER SET coupling adapter to the hydraulic rock drill.

2. Rotary-percussive self-drilling installation with a single-use drill bit; flushing of the cuttings through the annular gap between the drill rod and the AT – TUBESPILE™ vacuum lance.

3. Completion of the drilling process after reaching the final drilling depth.

4. Retraction of the POWER SET drill rod from the installed AT – TUBESPILE™ vacuum lance; the single-use drill bit remains in the borehole.

5. Insertion of a filter tube into the AT – TUBESPILE™ vacuum lance.

6. Optional: connection of a drainage hose and coupling onto a vacuum pump.

Accessories

- Vacuum pump
- DSI Inject Systems
- Injection packers

AT – Drainage System

Introduction

The AT – Drainage System is used for deep reaching drainage and forms a part of the AT-SYSTEM product family. It is used in Tunneling and in civil engineering for dewatering of the surrounding ground and consists of an inner steel tube which is encased with a PVC filter pipe.

The AT – Drainage System can be applied temporarily as well as semi-permanently. Examples of application are drainage works parallel to tunnel advances or water saturated slopes.

Main Advantages

- Installation using conventional drilling machines
- Execution of the drilling works can be carried out by on-site personnel guided by application engineers
- Time-saving self-drilling installation thanks to simultaneous drilling and casing
- Installation is also possible in flowing and ravelling ground conditions
- Length of the drainage tubes adaptable to limited space conditions

System Description

The AT – Drainage System is installed piecewise by rotary-percussive drilling using top hammer equipment. Cooling, flushing, and back-flushing of the cuttings takes place inside the cased system.

After installation, dewatering of the surrounding ground starts immediately. If required, the system can be connected to a vacuum pump.

System Components

AT – Drainage Starter Unit with Drill Bit

AT – Drainage Extension Tube

AT – Drainage End Tube

Drill Bit Adapter

Coupling Adapter and Drill Rods

End Cap with Ball Valve

Ready-For-Use AT – Drainage System
AT – 76/DR Starter Unit with DR Extension Tube

Specifications [1)]

System	Inner Tube Material	Filter Pipe [3)]	Outer Diameter		Weight		Standard Tube Length	
[–]	[–]	[–]	[mm]	[kg/m]	[kg/m]	[lb/ft]	[m]	[ft]
AT – 76/DR	Steel [2)]	PVC	76,1	3,0	7,0	4,7	3,0	9,8
AT – 118/DR	Steel [2)]	PVC	118	4,7	22,7	15,3	3,05	10

1) Different dimensions are available upon request.

2) Steel grade ≥ S235 according to EN 10025-2 or reference steel grade 35 [ksi].

3) Slot opening widths 0,6 [mm], 1,0 [mm], and 1,5 [mm] (1/32, 3/64, and 1/16 [in]); 3 slots around the whole pipe circumference.

Technical Features

- Fast length adaption of drainage tubes by piecewise installation
- Simple extension of drainage tubes even in limited space
- High directional accuracy of drainage drillings
- Drainage pipes can be flushed for cleaning purposes when installed as a permanent measure

Installation Procedure

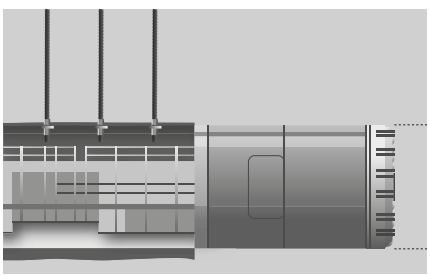
1. The starter unit with drill bit and the first drainage extension tube on the outside and the drill bit adapter with the drill rod on the inside is prepared for installation on the drill boom.
2. Drilling of the first drainage extension tube.
3. The next drill rod including the drainage extension tube is connected to the previously installed part and is subsequently drilled.
4. Repetition of the last step until the final length of the drainage drilling has been reached.

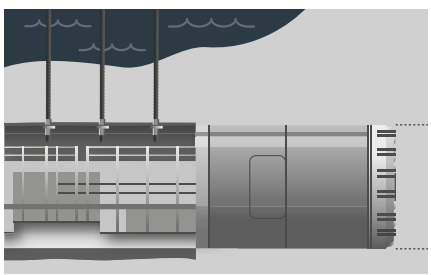
Accessories

- Chain pipe and drill rod wrench
- Rock drilling equipment: shank adapter, coupling, and coupling adapter
- Fishing tab
- Centralizer

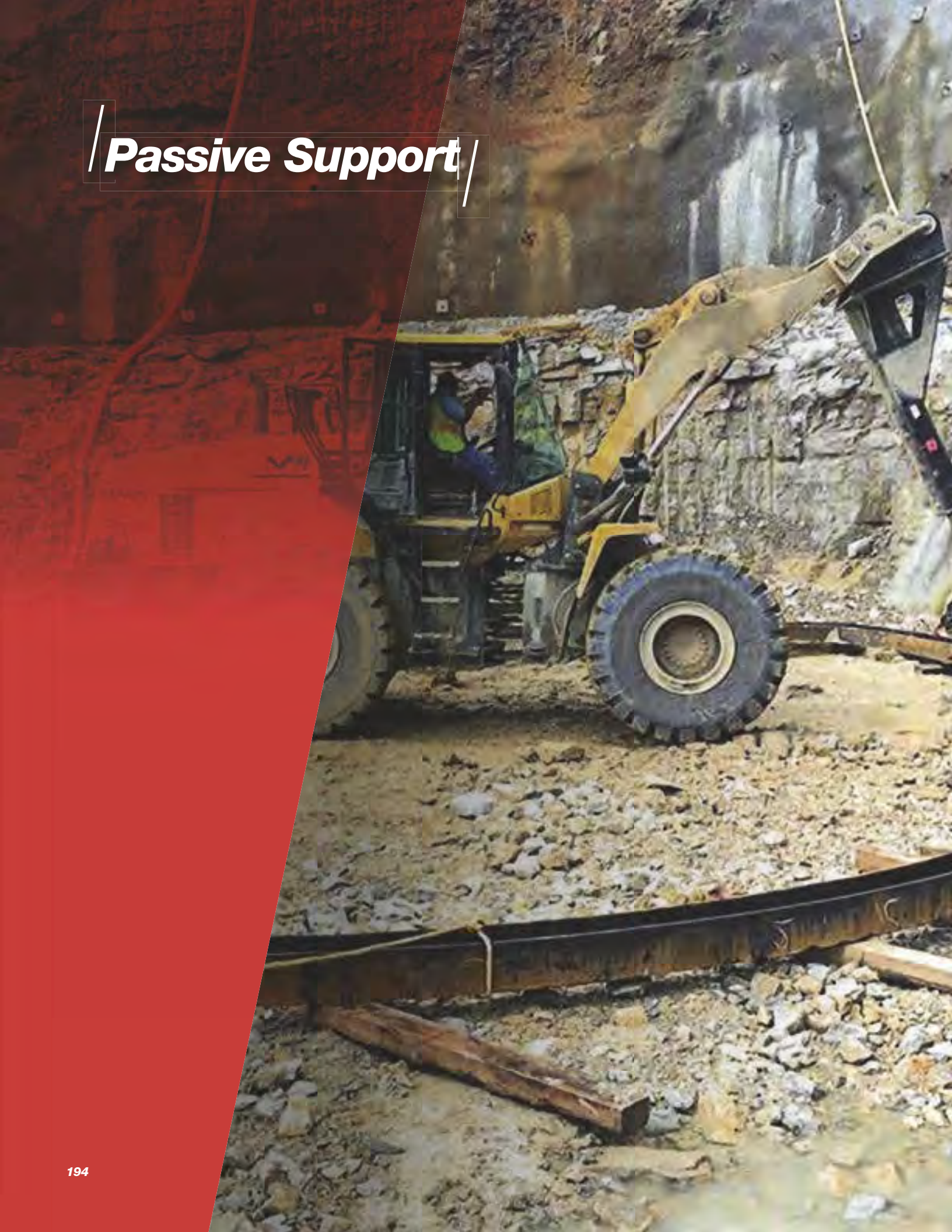
Mechanized Tunneling

The AT – Drainage System can be combined with fiberglass or PVC extension pipes for application in mechanized Tunneling.





Passive Support



Contents

Introduction

Passive support systems in Tunneling comprise of a group of ground control elements which are installed after excavation and inside the tunnel area, contrary to bolts which are installed into the ground. After installation, structural elements carry the load around the entire cross section or weights of individual blocks. In general, passive support is not installed with an applied loading, their loading goes hand in hand with excavation-induced deformations.

Installation of passive support followed by imposed ground deformations leads to the development of a supporting force in the excavation perimeter.
This supporting force increases with the deformations, until a state of equilibrium has been reached. Depending on ground conditions and the ground reaction (curve), a support system with an appropriate load line must be selected – for example stiff, yielding (ductile), or in some cases even soft.

A particular challenge for the application of passive support is squeezing or swelling ground, where the stress level exceeds ground or even rock mass strength. Large time-dependent deformations require installation of an additional yielding support system integrated in the shotcrete or concrete lining, like LSC™ Elements (lining stress controllers).

Passive support systems for Tunneling provided by DSI Underground are different types of steel ribs and lattice girders, liner plates, LSC™ Elements, as well as the BULLFLEX® Support System.
Other passive support systems commonly used are shotcrete, cast-in-place concrete, or concrete segments.

Steel Ribs

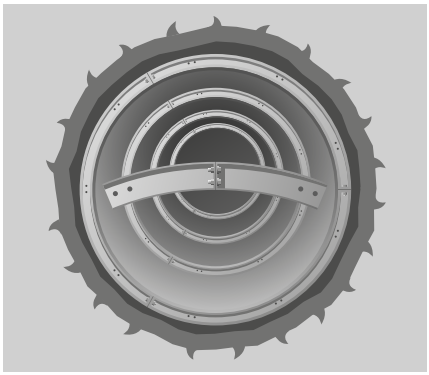
Steel ribs are efficient and safe ground control elements in Tunneling. Selection of section types and dimensions is accomplished in accordance with structural and project requirements. In addition to custom-bent steel ribs, straight beams, forepoling sheets, and steel lagging can also be fabricated.

Steel ribs are high-capacity load-carrying elements, hence their efficiency depends on the quality of the blocking which influences load transmission from the steel ribs to the ground. Use of steel ribs in combination with BULLFLEX® roof support backfilling helps to overcome this shortcoming and increases the utilization rate of passive steel support. For support applications under large deformations, a yielding passive support system such as TH profiles may be required.

DSI Underground has manufactured cold-formed beams for underground support applications since 1922, applying sound techniques for shaping steel required in the Tunneling industry. Techniques learned about shaping steel for strength, performance, and value in the world's tunnels and shafts can be applied to the benefit for each project.

Typical applications for steel ribs are:

- Tunnel ribs
- Shaft rings and breakout structures
- Mine sets and overcasts



Lattice Girders

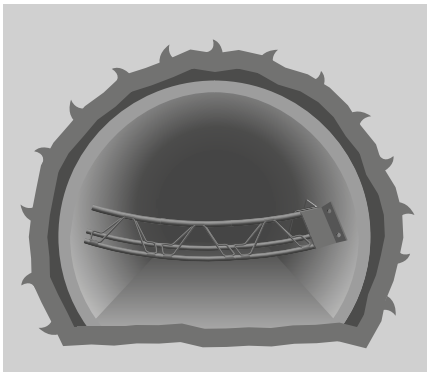
Lattice girders serve some of the same basic functions in Tunneling as steel arch supports. They form a part of the temporary lining which initially supports the excavation and, in some cases, are part of the finished lining. Lattice girder systems offer a very economical alternative to other support methods for a wide variety of ground conditions.

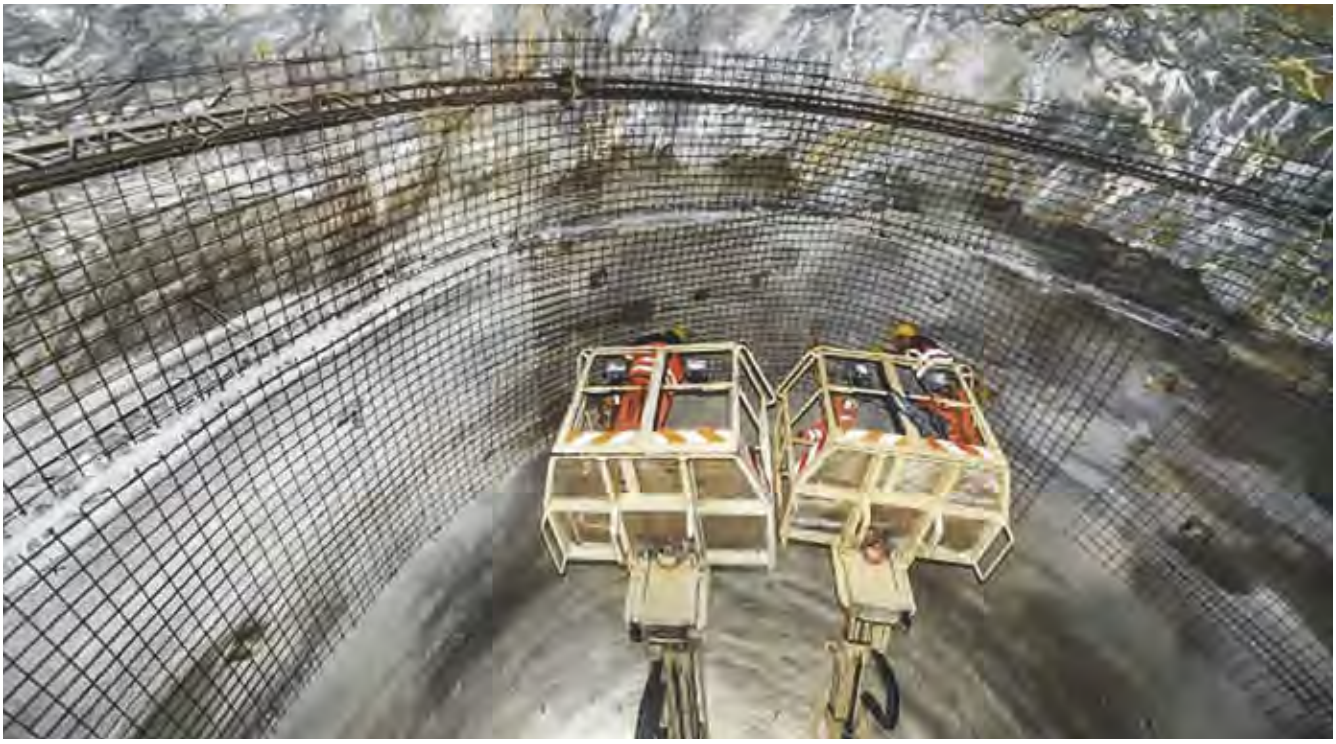
Use of lattice girders should be considered for projects where shotcrete will be used for temporary or permanent support. These include mining through soft ground, mixed face and rock, or tunnels in which widths or heights may vary.

Lattice girders are applied equally well to circular and horseshoe shaped excavations, whether driven full face or top heading and bench.

Lattice girders are commonly used for:

- NATM (SEM) excavation
- Passive support system for the excavated cross section
- Integral and reinforcing part of the shotcrete lining
- Profile template for the excavation geometry
- Bearing for pre-support elements





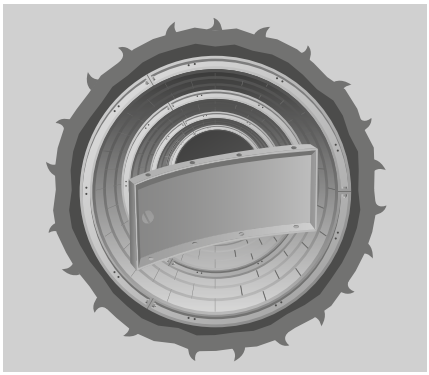
Liner Plates

Steel liner plates, which are bolted together to form a shell, are commonly used to provide temporary protective linings in the Tunneling industry. The first installation of steel liner plates dates to 1926 in the Moffat Tunnel in Colorado (US), which at the time was declared the year's outstanding engineering achievement. Liner plates ensure the stability of the tunnel and safety of the workers until more permanent ground reinforcement can be installed.

As the ground deforms to try and close the opening, the liner plate is radially stressed, and by deforming redistributes these loads back to the surrounding ground. Grouting behind the liner plates is done to fill any voids and ensure uniform contact to the strata around the back of the plates.

Another function of the liner plate in some applications is to act as a platform or structure for a (micro) tunnel boring machine to react against to develop the necessary forward thrust to be able to excavate the face. In this case, the liner plates are loaded axially as a horizontal column of bolted liner plate rings, creating a jacking force against the liner plate assembly.

Source: Barczak & Smith (2002)



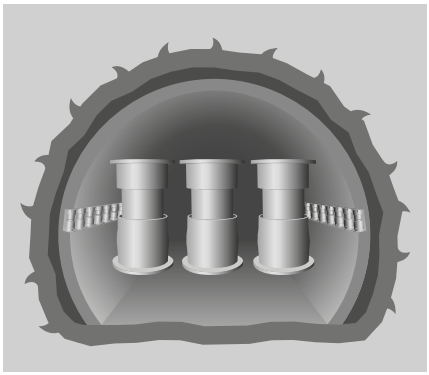
Typical applications for liner plates are:

- Ground support in conventional excavation
- Soft ground Tunneling
- Vertical and inclined tunnels
- TBM and MTBM jacking load resistance system
- Shaft and cofferdam support
- Smooth liner plates: shield excavation or tunnel boring machines
- Gasketed liner plates: hydrostatic conditions and reduction of water inflow
- Tapered liner plates: used for changes in alignment, both horizontally and vertically

LSC™ Elements

Underground excavation in weak ground combined with high overburden commonly results in large displacements.
Here, a stiff high-capacity passive support system is not the proper choice due to cost and safety constraints.
Lining stress controllers, ductile support systems integrated into the shotcrete lining, have been developed for such ground conditions.

Both displacements and shotcrete properties are time-dependent, this must be considered in the design and selection of the force-shortening characteristics of LSC™ Elements.
Loading of the shotcrete lining must be below the design strength, although utilization should be maximized.



Application of LSC™ Elements increases the occupational safety, limits the amount of displacements, and avoids incremental damage to both ground and shotcrete. Besides the use of ductile support systems such as LSC™ Elements, installation of bolts with an increased yielding ability is required.

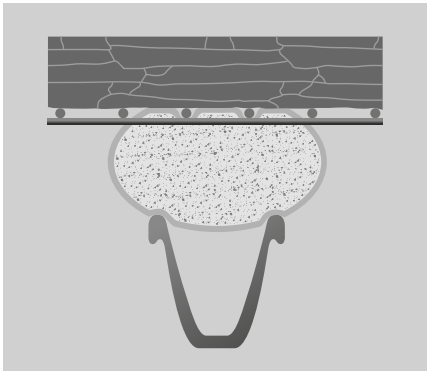
LSC™ Elements are used in the following ground conditions:

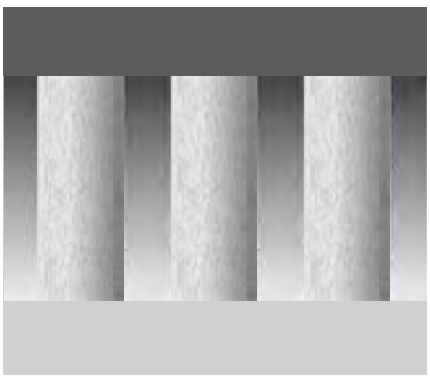
- Fault zones
- Swelling ground
- Squeezing ground

BULLFLEX® Support System

The BULLFLEX® support system is available for different applications:

- Support pillars
- Roof support backfilling and underpinning
- Roadway packs and dams
- Structural bulkheads
- Stoppings
- Structural sealings





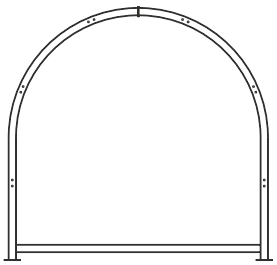
Steel Ribs

Main Advantages

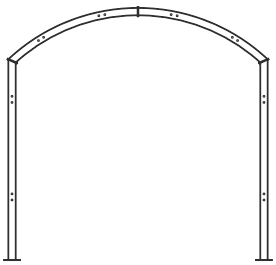
- Customized cold-formed beam constructions
- Various rib support types available upon request
- Flexible adaptation of the beam geometry to the respective excavated cross-section
- TH sections and other special support profiles available upon request
- Custom formed lagging resistant to machine jack thrusts and impact loads

Steel Rib Support Types

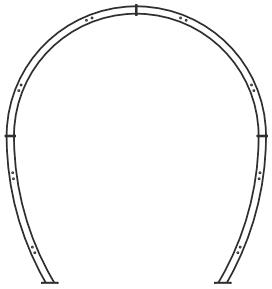
- Type 1:
  2 piece horseshoe with optional invert strut



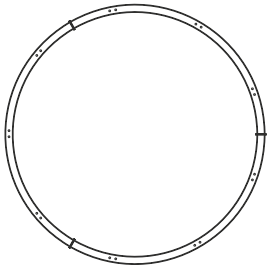
- Type 2:
  4 piece modified horseshoe



- Type 3:
  4 piece horseshoe



- Type 4:
  3 piece circular



Tunnel Ribs

Shaft Rings and Breakout Structures

Mine Sets and Overcasts

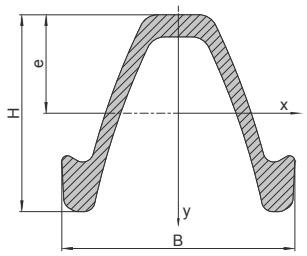
Steel Lagging

Steel Ribs (EMEA)

TH Profile

- Mine support steel 31Mn4 according to DIN 21544
- Bent to the corresponding profile
- Single overlapping segments are usually connected by two locks
- Different types of TH locks are available upon request

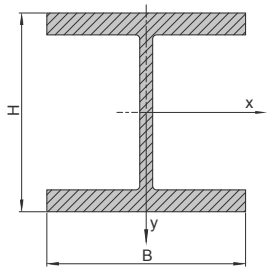
Characteristic Value / Type	Symbol	Unit	TH 21	TH 25	TH 29	TH 36
Nominal weight	m	[kg/m]	21	25	29	36
Profile height	H	[mm]	108	118	124	138
Profile width	B	[mm]	124	135	151	171
Neutral axis	e	[mm]	52	58	58	69
Section modulus	W_x	[cm³]	61	80	94	136



HEB Profile

- I profile – broad flange girder
- Primary material S235JRG2 or S355J2G3 according to EN 10025-2
- Bent to the corresponding profile
- Connection of the segments via head plates that are available in different designs
- Alternative connection of the abutting segments via laces
- Different lace types and lace screws are available upon request

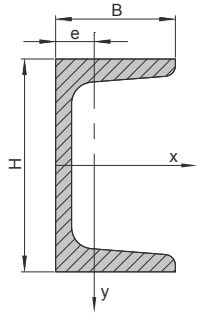
Characteristic Value / Type	Symbol	Unit	HEB 100	HEB 120	HEB 140
Nominal weight	m	[kg/m]	20,9	27,4	34,5
Profile height	H	[mm]	100	120	140
Profile width	B	[mm]	100	120	140
Section modulus	W_x	[cm³]	89,9	144,0	216,0
	W_y	[cm³]	33,5	52,9	78,5



UNP Profile

- U profile – flanges with inclined inner surfaces
- Primary material S235JRG2 or S355J2G3 according to EN 10025-2
- Bent to the corresponding profile
- Connection of the segments via welded-on and screwed head plates or flange connections
- Different lace types and lace screws are available upon request

Characteristic Value / Type	Symbol	Unit	UNP 80	UNP 100	UNP 120	UNP 140	UNP 160	UNP 180
Nominal weight	m	[kg/m]	8,6	10,6	13,4	16,4	18,8	22,0
Profile height	H	[mm]	80	100	120	140	160	180
Profile width	B	[mm]	45	50	55	60	65	70
Neutral axis	e	[cm]	1,45	1,55	1,60	1,75	1,84	1,92
Section modulus	W_y	[cm³]	6,4	8,5	11,1	14,8	18,3	22,4



Steel Ribs (North America)

Specifications US Customary Units

- Curvature range: minimum radius of 10 times the beam depth for 4" and 6" sections up and to 14 times for larger beams I, WF, and H sections from 4" to 27" (102 to 686 [mm]) in depth, bent to project requirements
- Butt joints
  - Height: rib depth plus 1"
  - Width: flange width plus 1"
- Tie rods
  - ASTM A529 Ø ¾" rod stock with 4" NC threaded both ends
  - Length: rib spacing plus 6"
  - Beam width 12" and above: structural spreaders are recommended
- Pipe spacers
  - Schedule 40 pipe stock Ø 2" (for Ø ¾" tie rods)
  - Length: rib spacing minus web thickness

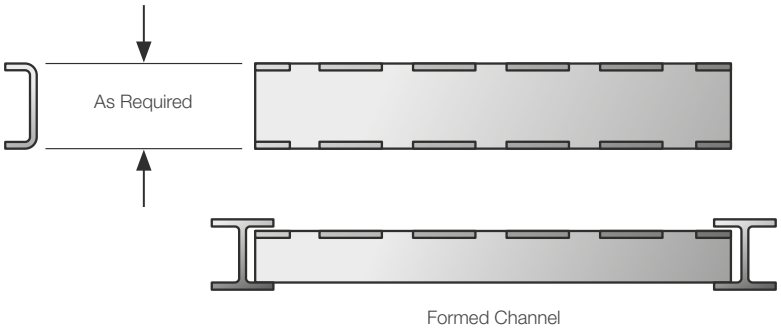
Joints and Foot Plates

Characteristic Value	Unit	4"	5"	6"	8"	10"	12"
Butt joint thickness	[in]	3/8	3/8	1/2	5/8	3/4	1
Bolt quantity [1)]	[1]	2	2	2	4	4	6
Bolt diameter [1)]	[in]	3/4	1	1	1	1	1
Foot plate dimensions	[in]	½" x 7" x 7"	5/8" x 9" x 9"	5/8" x 9" x 9"	¾" x 12" x 12"	1" x 14" x 14"	1¼" x 16" x 16"

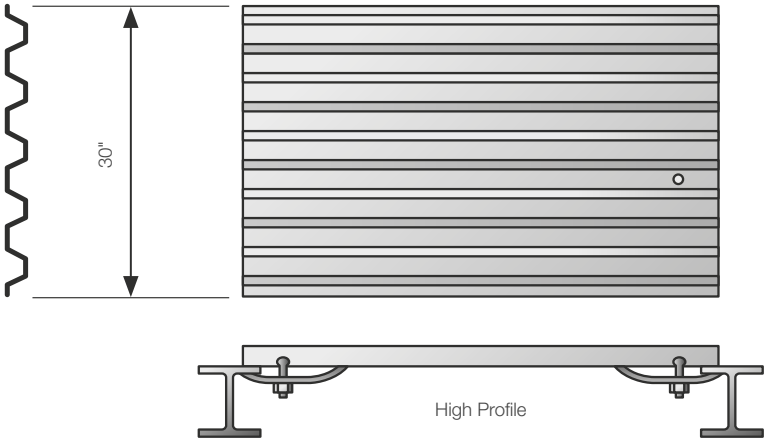
1) ASTM A325. For standard loading conditions; higher loads may require a full-moment strength joint.

Steel Lagging (North America)

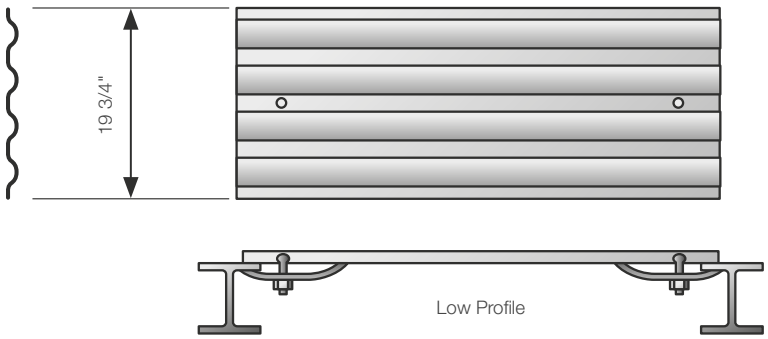
- Custom-formed as a replacement for wood lagging
- Placement on the inside or outside flange
- Low profile and high profile types
- Lagging clamp: 3" x 5" x 5" gage with square or round hole
- 5/8" diameter carriage bolt with nut



Formed Channel



High Profile



Low Profile

Lattice Girders

Introduction

Lattice girders have been developed for special demands in the field of Tunneling. The system has been extensively tested and used successfully for numerous tunnel projects throughout the world.

Lattice girders ensure an immediate support in the open span area. Contrary to standard solid-web girders, lattice girders are entirely integrated in the shotcrete lining; porous zones and shotcrete spray shadows are avoided.

The load-bearing capacity of lattice girders has been investigated in terms of various loading tests and by numerical analysis. Flexibility regarding geometry and bearing capacity characterizes this passive support system for underground applications.

Main Advantages

- Immediate support in the excavation area
- Partial static support action even without shotcrete embedding
- Utilization as a true-to-form template for shotcrete application
- Easy and quick assembly
- Simple handling and installation by a small crew
- Optimum bond and interconnection with the shotcrete lining
- Simple adjustment and shaping to the excavation geometry
- Ideal bearing for spiles and lagging boards
- Spiles may be installed both above or through the lattice girders
- No need for investment in major equipment

System Description

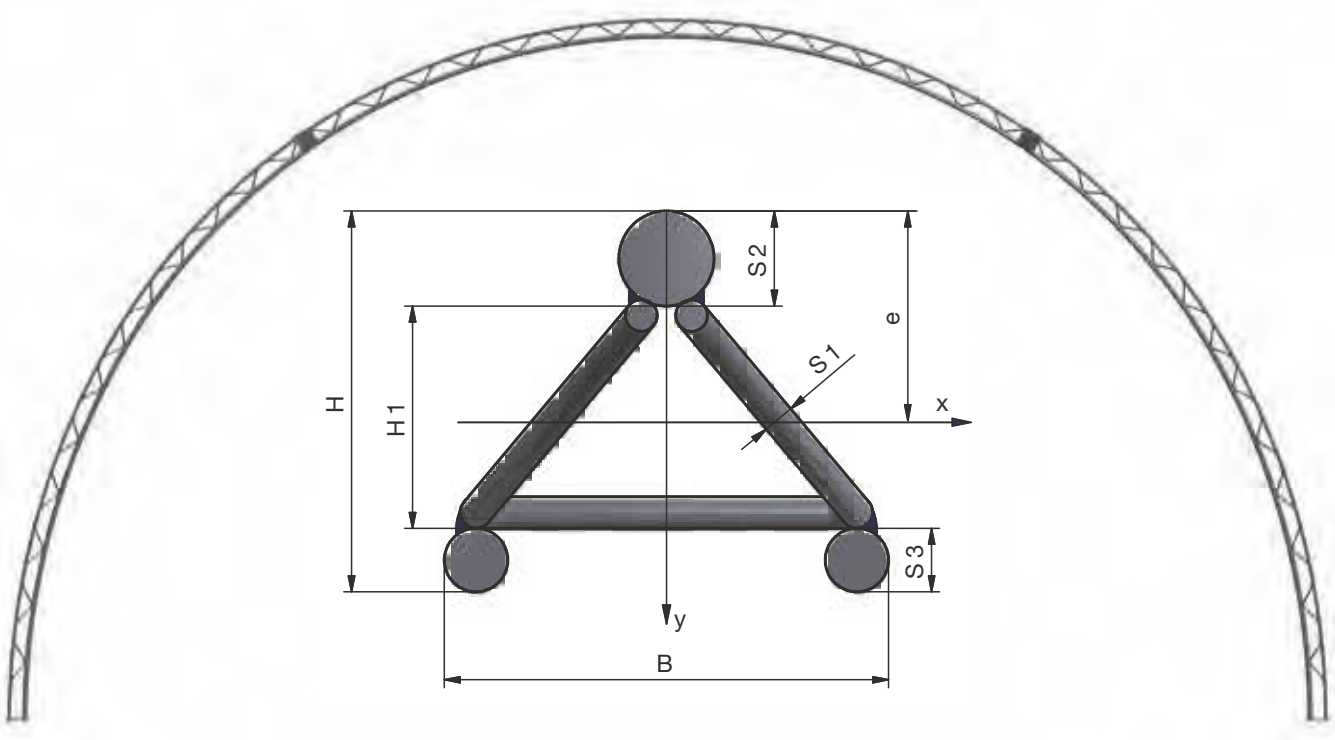
- Load-bearing elements according to the particular demands in Tunneling
- Application in combination with shotcrete
- Spatial 3-bar or 4-bar girder construction, connected via stiffening elements (spiders or welded rebars)
- Reduction of girder buckling lengths by stiffeners
- 3-bar girder: single bar by default at the excavation side
- 4-bar girder: application as wallplate beam or stiff cross girder
- Caverns with side drifts: combined use of 3-bar and 4-bar bar girders
- Assembly of the full girder profile by connecting single girder elements
- Load transmission even before shotcrete application
- Integral part of the shotcrete lining reinforcement
- Proven bond according to the design principles of reinforced concrete

System Components

Due to different regional steel (rebar), welding, and manufacturing standards, system components vary. This applies in particular to the type of stiffeners being used. Two common types are so-called spiders as well as welded rebar stiffeners.

Detailed specifications are included in local technical product brochures. In any case, section modulus (W or S) and/or second moment of area (I) are the relevant design parameters. This catalogue presents standard specifications of 3-bar and 4-bar spider girders.

However, lattice girder types with a greater variety of different rebar diameters and dimensions, hence equivalent design parameters, are part of the DSI Underground portfolio.



Manufacturing Standards

Region	Girder Bars	Spiders or Rebar Stiffeners	Connections	Welding Process
North America	– Smooth special grade reinforcing steel – ASTM A572 grade 65 – Yield strength ≥ 70 [ksi] (480 [MPa]) – Tensile strength ≥ 80 [ksi] (550 [MPa]) – Elongation ≥ 10%	– Spiders: ASTM A572 grade 70	– Plates: steel grade ASTM A36 or higher – Connecting bolts: ASTM A325N or higher	– According to AWS requirements for gas metal arc welding (GMAW) – Certified welders in accordance with AWS D1.1
	– Smooth special grade reinforcing steel ASTM A615 grade 75 – Yield strength ≥ 75 [ksi] (520 [MPa]) – Tensile strength ≥ 100 [ksi] (690 [MPa]) – Elongation ≥ 7% – Alternative: deformed ASTM A615 grade 60	– Spiders: ASTM A615 grade 60	– Connecting bolts: ASTM A307	– Welding specification AWS D1.4-98 – Welding wire specification AWS A5.18 ER-70S-G
Chile	– Ribbed reinforcing steel (deformed bar) – Mechanical properties: ASTM A615 grade 60 (Chilean standard NCH 204) – Chemical properties: ASTM A706 (enhanced weldability, Chilean standard NCH 3334) – Yield strength ≥ 420 [MPa] (61 [ksi]) – Tensile strength ≥ 630 [MPa] (91 [ksi]) – Elongation ≥ 8% (200 [mm] measuring length)	– Spiders: ribbed reinforcing steel (deformed bar) – Specifications: see girder bars	– Plates and angles: steel grade ASTM A36 or equivalent – Connecting bolts: ASTM A325 or higher	– MIG welding process (GMAW)
Colombia	– Ribbed reinforcing steel (deformed bar) – Grade NTC 2289 (ASTM A706/A706M) – Yield strength ≥ 420 [MPa] (60 [ksi]) – Tensile strength ≥ 550 [MPa] (80 [ksi])	– Spiders: round reinforcing steel – NTC 161 grade AH - 24 (SAE 1015) – Yield strength ≥ 235 [MPa] (34 [ksi]) – Tensile strength ≥ 363 [MPa] (53 [ksi])	– Plates and angles: steel grade ASTM A36 or equivalent – Connecting bolts and nuts: SAE J995 G8	– According to AWS requirements for gas metal arc welding (GMAW) – Certified welders in accordance with AWS D1.1
Argentina	– Ribbed reinforcing steel (deformed bar) – Grade ADN 420 (weldable), IRAM-IAS-U-500-207 – Yield strength ≥ 420 [MPa] (60 [ksi]) – Tensile strength ≥ 500 [MPa] (73 [ksi]) – Elongation ≥ 12%	– Spiders: ribbed reinforcing steel (deformed bar) – Specifications: see girder bars	– Plates and angles: steel grade ASTM A36 or equivalent – Connecting bolts: ASTM A325 or higher	– According to AWS requirements for gas metal arc welding (GMAW) – Certified welders in accordance with AWS D1.1
Perú	– Ribbed reinforcing steel (deformed bar) – Grade ASTM A706 grade 60 – Yield strength ≥ 420 [MPa] (60 [ksi]) – Tensile strength ≥ 550 [MPa] (80 [ksi] – Elongation ≥ 12%	– Spiders: ribbed reinforcing steel (deformed bar) – Specifications: see girder bars	– Plates and angles: steel grade ASTM A36 or equivalent – Connecting bolts: ASTM A325 or higher	– According to AWS requirements for gas metal arc welding (GMAW) – Certified welders in accordance with AWS D1.1
EMEA	– Ribbed reinforcing steel – B 500 B or higher – DIN 488-1, OENORM B 4700, or similar	– Stiffeners: DIN 488-1, OENORM B 4700, or similar	– Plates: S235 (EN 10025-2) – Connecting bolts: 8,8 (EN ISO 898-1) or higher – Allowable tightening torques and mounting pre-load for set metrical screws: VDI guideline No. 2230, sheet 1	– DSI Underground factory specifications
APAC	– Ribbed reinforced steel – AS 4671	– Spiders: A1018 or higher	– Plates: AS 3678-250 – Structural bolt assemblies: AS 1252	– In accordance with AS 1554
	– Smooth special grade reinforcing steel ASTM A615 grade 75 – Yield strength ≥ 75 [ksi] (520 [MPa]) – Tensile strength ≥ 100 [ksi] (690 [MPa]) – Elongation ≥ 7% – Alternative: deformed ASTM A615 grade 60	– Spiders: ASTM A615 grade 60	– Connecting bolts: ASTM A307	– Welding specification AWS D1.4-98 – Welding wire specification AWS A5.18 ER-70S-G

Specifications 3-Bar Spider Girders

SI Units

Designation	S1	S2	S3	Weight [2]	H	B	A	W_x [3]
[H/S3-S2/B]	[mm]	[mm]	[mm]	[kg/m]	[mm]	[mm]	[cm^2]	[cm^3]
100/18-25/100	10	25	18	7,9	100	100	10,00	30
100/20-28/100	10	28	20	9,8			12,44	35
100/20-30/100	10	30	20	10,5			13,35	38
100/22-32/100	10	32	22	12,3			15,65	42
120/18-25/140	10	25	18	7,9	120	140	10,00	39
120/20-28/140	10	28	20	9,8			12,44	47
120/20-30/140	10	30	20	10,5			13,35	51
120/22-32/140	10	32	22	12,3			15,65	56
145/18-25/180	10	25	18	7,9	145	180	10,00	51
145/20-28/180	10	28	20	9,8			12,44	61
145/20-30/180	10	30	20	10,5			13,35	66
145/22-32/180	10	32	22	12,3			15,65	75
165/18-25/180	10	25	18	7,9	165	180	10,00	60
165/20-28/180	10	28	20	9,8			12,44	73
165/20-30/180	12	30	20	10,5			13,35	78
165/22-32/180	12	32	22	12,3			15,65	90
185/18-25/200	12	25	18	7,9	185	200	10,00	70
185/20-28/200	12	28	20	9,8			12,44	85
185/20-30/200	12	30	20	10,5			13,35	90
185/22-32/200	12	32	22	12,3			15,65	106
220/18-25/200	12	25	18	7,9	220	200	10,00	87
220/20-28/200	12	28	20	9,8			12,44	106
220/20-30/200	12	30	20	10,5			13,35	112
220/22-32/200	12	32	22	12,3			15,65	133

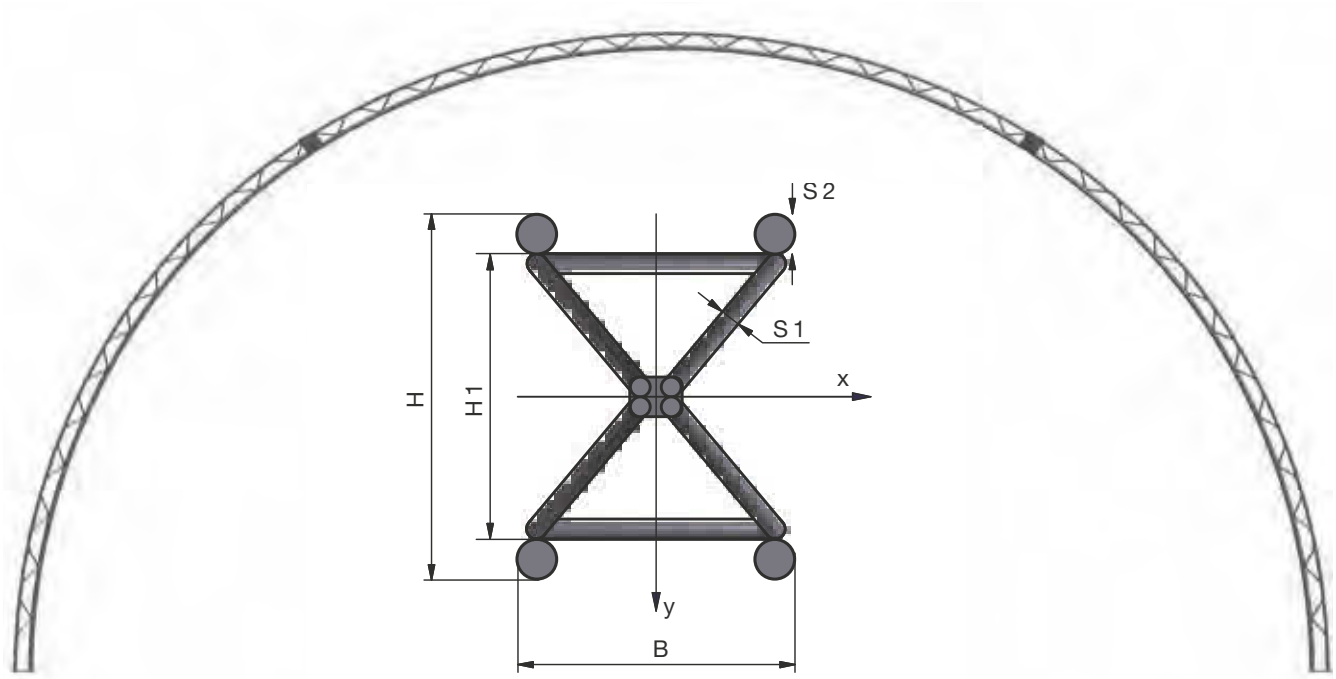
US Customary Units

CP Size H 1 [1]		Bar Size			Weight [2]	H	B	e	I_x	S_x [3]	I_y	S_y [3]
		S3	S2	S1								
[mm]	[in]	[#]	[#]	[in]	[lb/ft]	[in]	[in]	[in]	[in^4]	[in^3]	[in^4]	[in^3]
50	1,97	6	8	0,39	6,72	3,70	3,94	2,01	3,44	1,72	2,32	1,18
		6	10		8,26	3,94		1,88	4,68	2,23	2,40	1,22
70	2,75	6	8	0,39	6,95	4,50	5,50	2,42	5,54	2,30	5,06	1,85
		6	10		8,59	4,77		2,20	7,38	2,89	5,14	1,87
		8	11		11,93	5,16		2,69	12,11	4,47	8,23	2,99
95	3,75	6	8	0,39	7,07	5,50	7,09	2,94	8,94	3,04	8,95	2,53
		6	10		8,70	5,77		2,59	11,74	3,75	9,03	2,55
		8	11		12,05	6,16		3,18	18,88	5,85	14,84	4,19
115	4,50	6	8	0,47	7,94	6,25	8,66	3,37	12,18	3,64	13,91	3,21
		6	10		9,58	6,52		2,91	15,85	4,42	13,99	3,23
		8	11		12,92	6,91		3,63	25,21	6,95	23,34	5,39
130	5,12	6	8	0,47	7,76	6,87	8,66	3,67	15,02	4,09	13,91	3,21
		6	10		9,39	7,14		3,15	19,38	4,93	13,98	3,23
		8	11		12,73	7,53		3,93	30,62	7,79	23,34	5,39

1) Designation: CPH1-S3-S2, e.g. CP130-6-8.

2) Approximate weight including spiders (average values without joint and foot plates).

3) Quotient second moment of area and maximum distance from the neutral axis to the outer fiber.


S2
S1
x
H
H1
y
B

Specifications 4-Bar Spider Girders

SI Units

Designation [1]	Type	S1	S2	Weight [2]	H	B	A	W_x [3]	W_y [3]
[PS1-S2]	(H_1)	[mm]	[mm]	[kg/m]	[mm]	[mm]	[cm^2]	[cm^3]	[cm^3]
P100-20	100	10	20	12,6	140	100	12,57	65	41
P100-25		10	25	18,2	150		19,63	103	57
P100-30		10	30	25,0	160		28,27	151	72
P100-36		10	36	34,8	172		40,72	223	90
P140-20	140	10	20	13,1	180	140	12,57	90	65
P140-25		10	25	18,7	190		19,63	141	94
P140-30		10	30	25,5	200		28,27	206	124
P140-36		10	36	35,2	212		40,72	301	162
P190-20	190	10	20	13,8	230	180	12,57	121	90
P190-25		10	25	19,4	240		19,63	190	132
P190-30		10	30	26,2	250		28,27	275	178
P190-36		10	36	36,0	262		40,72	399	238
P230-20	230	12	20	14,4	270	220	12,57	146	115
P230-25		12	25	19,9	280		19,63	229	170
P230-30		12	30	26,7	290		28,27	331	233
P230-36		12	36	36,5	302		40,72	479	316
P260-20	260	12	20	14,7	300	220	12,57	164	115
P260-25		12	25	20,2	310		19,63	258	170
P260-30		12	30	27,0	320		28,27	373	233
P260-36		12	36	36,8	332		40,72	539	316

US Customary Units

CP Size H_1 [1]		S1	Bar Size S2	Weight [2]	H	B	A Bars	I_x	S_x [3]	I_y	S_y [3]
[mm]	[in]	[mm]	[#]	[lb/ft]	[in]	[in]	[in^2]	[in^4]	[in^3]	[in^4]	[in^3]
100	3,94	10	5	7,61	5,19	3,94	1,2	6,42	2,47	3,40	1,72
			6	8,88	5,44		1,8	9,77	3,59	4,55	2,31
			7	10,23	5,69		2,4	14,04	4,94	5,75	2,92
			8	13,43	5,94		3,1	19,34	6,52	6,97	3,54
			10	17,16	6,44		4,9	33,50	10,41	9,34	4,75
140	5,51	10	5	7,88	6,76	5,51	1,2	11,54	3,42	7,32	2,66
			6	9,14	7,01		1,8	17,32	4,95	10,03	3,65
			7	10,51	7,26		2,4	24,55	6,77	12,98	4,72
			8	13,71	7,51		3,1	33,38	8,90	16,10	5,86
			10	17,42	8,01		4,9	56,39	14,10	22,65	8,24
180	7,09	10	5	8,51	8,34	7,09	1,2	20,28	4,64	12,85	3,63
			6	9,78	8,59		1,8	30,13	6,70	17,82	5,03
			7	11,15	8,84		2,4	42,29	9,14	23,34	6,58
			8	14,35	9,09		3,1	56,94	11,99	29,32	8,27
			10	18,06	9,59		4,9	94,44	18,89	42,33	11,94
220	8,66	12	5	9,80	9,91	8,66	1,2	28,45	5,55	19,84	4,58
			6	11,06	10,16		1,8	42,06	8,01	27,71	6,40
			7	12,43	10,41		2,4	58,75	10,93	36,57	8,44
			8	15,63	10,66		3,1	78,74	14,32	46,29	10,65
			10	19,34	11,16		4,9	129,41	22,51	67,88	15,68

1) Designation: CPH1-S2, e.g.CP100-8.

2) Approximate weight including spiders (average values without joint and foot plates).

3) Quotient second moment of area and maximum distance from the neutral axis to the outer fiber.

Wallplate Beams

- 4-bar girders can be used as wallplate beams for top heading drives
- Installation of 90° axial rotated 4-bar girders in the longitudinal direction
- Wallplate beams serve as bearing and profile template for installation of the girder arch
- Bend-proof frontal connection allows free top heading advancing
- At the same time, wallplate beams are considered as statically effective reinforcement for the foot beam

Joint and Foot Plates

3-Bar and 4-Bar Girders (North America)

CP Size	Joint Plate			Foot Plate	
	Size	Length	Unit Weight	Size	Unit Weight
[mm]	[in]	[in]	[lb]	[in]	[lb]
50	L4 x 3 x 3/8	4 9/16	3,2	3/8 x 5 x 5	2,7
		4 9/16	3,2		
70		5 5/16	3,5	3/8 x 6 x 6	3,8
		5 1/2	3,7		
		5 3/4	3,9		
95		6 9/16	4,4	3/8 x 7 x 8	6,0
		6 3/4	4,6		
		7 1/16	4,8		
115	L5 x 3 x 1/2	7 11/16	8,0	3/8 x 8 x 9 1/2	8,1
		7 13/16	8,1		
		8 1/8	8,4		
130		8 1/8	8,4	3/8 x 8 x 9 1/2	8,1
		8 5/16	8,6		
		8 3/4	9,3		

CP Size	Joint Plate			Foot Plate	
	Size	Length	Unit Weight	Size	Unit Weight
[mm]	[in]	[in]	[lb]	[in]	[lb]
100	L5 x 3 x 1/2	5 1/4	5,6	1/2 x 5 x 7	5,0
		5 1/2	5,9		
		5 3/4	6,1		
		6	6,4		
		6 1/2	6,9		
140		6 3/4	7,2	1/2 x 7 x 9	8,3
		7	7,5		
		7 1/4	7,7		
		7 1/2	8,0		
		8	8,5		
180		8 3/8	8,9	1/2 x 8 x 10 1/2	11,9
		8 5/8	9,2		
		8 7/8	9,5		
		9 1/8	9,7		
		9 5/8	10,3		
220		9 15/16	10,6	5/8 x 10 x 12	21,2
		10 3/16	10,9		
		10 7/8	11,1		
		10 11/16	11,8		
		11 3/16	11,9		

Liner Plates

Introduction

4-flange steel liner plates, a system which has been successfully used since 1926, provide light-weight, easy-to-handle, and safe support for soft ground Tunneling and shaft construction made in the USA (Louisville, Kentucky).

4-flange liner plates manufactured by DSI Underground are available in 400 and 610 [mm] (16" and 24") widths as corrugated or smooth plates. Liner plates are formed from one piece of steel to provide longitudinal and circumferential flanges with optimum load-bearing and bending resistance characteristics.

4-flange liner plates can be galvanized, bitumen coated, or polymer coated. Grout holes and plugs can also be coated. For special conditions, gasketed liner plates and tapered liner plates can also be manufactured. Liner plates are installed as stand alone structures or in conjunction with steel ribs if additional support is required.

Standard diameters of tunnels and shafts supported solely with 4-flange liner plates can vary from 1,2 to 6,1 [m] (4" to 20").

The liner plate assembly simply distributes and transmits the load to the surrounding ground. As a steel liner plate ring takes load vertically, it tends to deflect inward at the top and outward at the sides. Thereby, the ground resists deflection of the lining by developing a passive force equal in magnitude and opposite in direction to the force exerted by that of the lining.

Main Advantages

- Optimized cycle times and manpower requirements
- Maximum consistent passive support strength with minimum weight of steel
- Safe support system
- Easy to store, handle, and erect
- Flexible design for different tunnel geometries and ground conditions
- Fire resistant system components
- Optional gasket plates for sealing of joints available upon request
- DSI Underground's 4-flange smooth liner plates are the only liner plate type capable of resisting tunnel boring machine jacking loads without any supplemental structural support

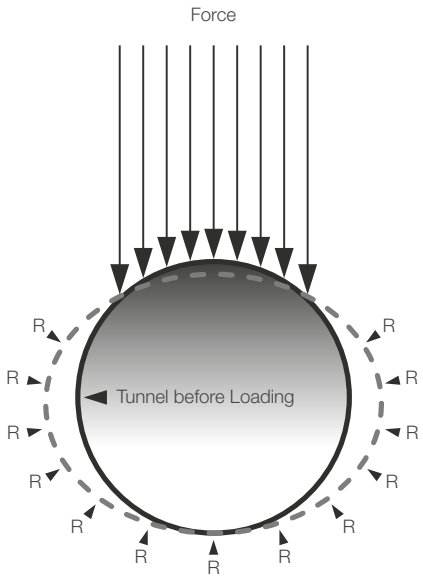
System Description

4-flange steel liner plates provide a relatively light-weight, easy-to-handle, and safe support for soft ground Tunneling, because the ground that supplies the loading also supplies the respective resistance. The liner plate assembly simply distributes and transmits the load to the surrounding ground. As a steel liner plate ring takes load vertically, it tends to deflect inward at the top and outward at the sides. The ground resists deflection of the lining by developing a passive force equal in magnitude and opposite in direction to the force exerted by that of the lining.

The ability of the surrounding ground to resist the outward bulge of the liner plate ring is the key to vertical load support. With the ring confined to a small amount of deflection, the thrust line induced by the load is forced to follow the ring of liner plates. Thus, the ability of the assembly to withstand the applied load depends upon its ability to transmit ring thrust from plate to plate around the ring. Obviously, this ability is enhanced by the 4-flange design of DSI Underground.

There are various methods for determining the required strength of tunnel linings. Type of ground, location, and depth of cover, size and length of the tunnel, level of ground water, superimposed loading, and history always guide these calculations.
Designs from DSI Underground conform to the latest guidance of AASHTO (American Association of State Highway and Transportation Officials) and AREMA (The American Railway Engineering and Maintenance-of-Way Association).

Diagram of Load and Load Reactions



R = Ground Resistance

System Components

- Cold-formed 4-flange steel liner plates, 406 and 610 [mm] (16" and 24") widths
- Thicknesses of 12, 10, 8, 7, 5, 3 gages (gauges), 5/16", or 3/8" (8 or 9,5 [mm]) available
- Corrugated or smooth plate, steel grade according to ASTM A1011
- Galvanized (ASTM A 123) and/or bitumen coated (AASHTO M190) versions available
- Customized partial plates are available to meet specific dimensions
- Liner plate gaskets and 51 [mm] (2") grout holes available upon request
- Bolts and nuts with quick acting coarse thread according to ASTM A 307 (hot-dip galvanized: ASTM A 153)
- Polymer coating according to the aerospace standard SAE AS1003

Specifications

Permissible Safe Loads on Circular Tunnels of Various Diameters or Arches for 16" Wide Corrugated Liner Plates [1)]

SI Units

Safe Load Table (Loads in [kN/m²])

Thickness [mm]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	2,66	3,42	4,18	4,55	5,31	6,07	7,94	9,53
Diameter [m]								
1,2	208	342	399	431	530	602	776	925
1,5	166	273	319	345	424	482	621	740
1,8	138	228	266	287	353	401	517	617
2,1	119	195	228	246	303	344	443	529
2,4	104	171	199	215	265	301	388	463
2,7		143	177	192	236	268	345	411
3,0		111	147	160	202	225	310	370
3,4			114	124	161	179	258	323
3,7				96	126	139	207	265
4,0					99	109	164	213
4,3					79	87	131	170
4,6							107	139
4,9							88	114
5,2							73	95
5,5								80
5,8								68
6,1								58

US Customary Units

Safe Load Table (Loads in [psf])

Thickness [ft]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	0,1046	0,1345	0,1644	0,1793	0,2092	0,2391	0,3125	0,375
Diameter [ft]								
4	4 335	7 135	8 335	9 000	11 075	12 580	16 200	19 320
5	3 465	5 710	6 665	7 200	8 860	10 065	12 960	15 455
6	2 890	4 755	5 555	6 000	7 380	8 385	10 800	12 880
7	2 475	4 080	4 760	5 145	6 325	7 190	9 260	11 040
8	2 165	3 570	4 165	4 500	5 535	6 290	8 100	9 660
9		2 985	3 705	4 000	4 920	5 590	7 200	8 585
10		2 310	3 080	3 350	4 220	4 705	6 480	7 730
11			2 380	2 590	3 370	3 735	5 380	6 755
12				1 995	2 635	2 900	4 330	5 535
13					2 070	2 280	3 420	4 445
14					1 660	1 825	2 740	3 560
15							2 225	2 895
16							1 835	2 385
17							1 530	1 990
18								1 675
19								1 425
20								1 220

1) Note: 4-flange liner plates for tunnel diameters other than those shown in the tables are available. Please refer to DSI Underground engineering staff for a safe load determination outline.

Sectional Properties for 16" Wide Corrugated Liner Plates

SI Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[mm]	[mm]	[mm]	[mm]	[mm²]	[mm²/mm]	[mm²/mm]	[mm⁴]	[mm⁴/mm]	[mm]	[kg]	[kg]
12	2,7	16	49	51	1 372	3,4	1,73	2 816 166	693	14,2	11,0	5,9
10	3,4	16	49	51	1 754	4,3	2,21	3 657 769	900	14,5	14,2	7,5
8	4,2	17	51	54	2 158	5,3	2,72	4 945 563	1 218	15,2	17,3	9,3
7	4,6	17	51	54	2 346	5,8	2,95	5 395 917	1 327	15,2	18,6	9,8
5	5,3	18	54	57	2 721	6,7	3,43	7 195 666	1 771	16,3	22,0	11,9
3	6,1	18	53	57	3 092	7,6	3,89	7 969 008	1 962	16,0	24,9	13,1
5/16"	7,9	19	55	60	3 982	9,8	5,01	11 828 229	2 910	17,3	31,1	16,4
3/8"	9,5	23	55	64	4 748	11,7	5,98	15 408 581	3 792	18,0	37,3	19,6

US Customary Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[in]	[in]	[in]	[in]	[in²]	[in²/in]	[in²/ft]	[in⁴]	[in⁴/in]	[in]	[lb]	[lb]
12	0,10	0,61	1,95	2,00	2,13	0,13	0,80	0,68	0,04	0,56	24,2	12,9
10	0,13	0,62	1,95	2,00	2,72	0,17	1,02	0,88	0,05	0,57	31,2	16,5
8	0,16	0,66	2,02	2,13	3,34	0,21	1,25	1,19	0,07	0,60	38,2	20,6
7	0,18	0,66	2,02	2,13	3,64	0,23	1,36	1,30	0,08	0,60	40,9	21,7
5	0,21	0,70	2,12	2,25	4,22	0,26	1,58	1,73	0,11	0,64	48,6	26,2
3	0,24	0,72	2,09	2,25	4,79	0,30	1,80	1,91	0,12	0,63	54,9	28,9
5/16"	0,31	0,76	2,17	2,38	6,17	0,39	2,31	2,84	0,18	0,68	68,6	36,1
3/8"	0,38	0,91	2,15	2,50	7,36	0,46	2,76	3,70	0,23	0,71	82,3	43,3

Permissible Safe Loads on Circular Tunnels of Various Diameters or Arches for 16" Wide Smooth Liner Plates [1)]

SI Units

Safe Load Table (Loads in [kN/m²])

Thickness [mm]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	2,66	3,42	4,18	4,55	5,31	6,07	7,94	9,53
Diameter [m]								
1,2	208	329	399	431	517	587	766	919
1,5	166	263	319	345	414	470	613	735
1,8	138	219	266	287	345	391	511	613
2,1		184	228	246	295	336	438	525
2,4			187	204	256	290	383	460
2,7			139	151	196	223	313	407
3,0					146	165	240	322
3,4					109	124	181	249
3,7						96	139	192
4,0							110	151
4,3							88	121
4,6								98
4,9								81
5,2								68
5,5								
5,8								
6,1								

US Customary Units

Safe Load Table (Loads in [psf])

Thickness [ft]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	0,1046	0,1345	0,1644	0,1793	0,2092	0,2391	0,3125	0,375
Diameter [ft]								
4	4 335	7 135	8 335	9 000	11 075	12 580	16 200	19 320
5	3 465	5 710	6 665	7 200	8 860	10 065	12 960	15 455
6	2 890	4 755	5 555	6 000	7 380	8 385	10 800	12 880
7	2 475	4 080	4 760	5 145	6 325	7 190	9 260	11 040
8	2 165	3 570	4 165	4 500	5 535	6 290	8 100	9 660
9		2 985	3 705	4 000	4 920	5 590	7 200	8 585
10		2 310	3 080	3 350	4 220	4 705	6 480	7 730
11			2 380	2 590	3 370	3 735	5 380	6 755
12				1 995	2 635	2 900	4 330	5 535
13					2 070	2 280	3 420	4 445
14					1 660	1 825	2 740	3 560
15							2 225	2 895
16							1 835	2 385
17							1 530	1 990
18								1 675
19								1 425
20								1 220

1) Note: 4-flange liner plates for tunnel diameters other than those shown in the tables are available. Please refer to DSI Underground engineering staff for a safe load determination outline.

Sectional Properties for 16" Wide Smooth Liner Plates

SI Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[mm]	[mm]	[mm]	[mm]	[mm²]	[mm²/mm]	[mm²/mm]	[mm⁴]	[mm⁴/mm]	[mm]	[kg]	[kg]
12	2,7	6	45	51	1 321	3,3	1,7	140 936	347	11,7	11,0	5,9
10	3,4	7	44	51	1 689	4,2	2,1	230 759	567	11,7	14,2	7,5
8	4,2	7	46	54	2 078	5,1	2,6	330 654	814	12,7	17,3	9,3
7	4,6	8	46	54	2 260	5,6	2,8	357 251	878	12,7	18,6	9,8
5	5,3	9	49	57	2 654	6,5	3,3	484 785	1 193	13,5	22,0	11,9
3	6,1	9	48	57	3 015	7,4	3,8	544 556	1 340	13,5	24,9	13,1
5/16"	7,9	10	50	60	3 931	9,7	5,0	803 077	1 976	14,2	31,1	16,4
3/8"	9,5	12	52	64	4 718	11,6	5,9	1 088 112	2 678	15,2	37,3	19,6

US Customary Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[in]	[in]	[in]	[in]	[in²]	[in²/in]	[in²/ft]	[in⁴]	[in⁴/in]	[in]	[lb]	[lb]
12	0,10	0,25	1,75	2,00	2,05	0,13	0,77	0,34	0,02	0,46	24,2	12,9
10	0,13	0,26	1,74	2,00	2,62	0,16	0,98	0,55	0,03	0,46	31,2	16,5
8	0,16	0,30	1,83	2,13	3,22	0,20	1,21	0,79	0,05	0,50	38,2	20,6
7	0,18	0,30	1,82	2,13	3,50	0,22	1,31	0,86	0,05	0,50	40,9	21,7
5	0,21	0,34	1,91	2,25	4,11	0,26	1,54	1,16	0,07	0,53	48,6	26,2
3	0,24	0,35	1,90	2,25	4,67	0,29	1,75	1,31	0,08	0,53	54,9	28,9
5/16"	0,31	0,41	1,97	2,38	6,09	0,38	2,29	1,93	0,12	0,56	68,6	36,1
3/8"	0,38	0,46	2,04	2,50	7,31	0,46	2,74	2,61	0,16	0,60	82,3	43,3

Permissible Safe Loads on Circular Tunnels of Various Diameters or Arches for 24" Wide Corrugated Liner Plates [1)]

SI Units

Safe Load Table (Loads in [kN/m²])

Thickness [mm]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	2,66	3,42	4,18	4,55	5,31	6,07	7,94	9,53
Diameter [m]								
1,2 [2)]	208	315	385	419	490	556	722	862
1,5	166	252	308	335	392	445	577	689
1,8	138	210	257	279	327	371	481	575
2,1	119	180	220	239	280	318	412	492
2,4		149	193	209	245	278	361	431
2,7			154	163	209	237	321	383
3,0			117	123	163	185	259	328
3,4					124	141	202	262
3,7					96	109	156	205
4,0							123	161
4,3							98	129
4,6							80	105
4,9								86
5,2								72
5,5								
5,8								
6,1								

US Customary Units

Safe Load Table (Loads in [psf])

Thickness [ft]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	0,1046	0,1345	0,1644	0,1793	0,2092	0,2391	0,3125	0,375
Diameter [ft]								
4 [2)]	4 335	6 570	8 045	8 750	10 230	11 615	15 075	18 000
5	3 465	5 255	6 440	7 000	8 185	9 295	12 060	14 400
6	2 890	4 380	5 365	5 830	6 820	7 745	10 050	12 000
7	2 475	3 755	4 600	5 000	5 845	6 640	8 615	10 285
8		3 115	4 025	4 375	5 115	5 810	7 535	9 000
9			3 215	3 410	4 365	4 955	6 700	8 000
10			2 440	2 560	3 410	3 870	5 410	6 855
11					2 595	2 945	4 225	5 480
12					2 000	2 270	3 255	4 280
13							2 560	3 365
14							2 050	2 695
15							1 665	2 190
16								1 805
17								1 505
18								
19								
20								

1) Note: 4-flange liner plates for tunnel diameters other than those shown in the tables are available. Please refer to DSI Underground engineering staff for a safe load determination outline.

2) Not recommended for circular tunnel applications.

Sectional Properties for 24" Wide Corrugated Liner Plates

SI Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[mm]	[mm]	[mm]	[mm]	[mm²]	[mm²/mm]	[mm²/mm]	[mm⁴]	[mm⁴/mm]	[mm]	[kg]	[kg]
12	2,7	15	52	51	1 895	3,1	1,6	325 992	534	13,2	15,6	8,5
10	3,4	15	52	51	2 421	4,0	2,0	412 485	677	13,0	20,0	10,7
8	4,2	16	54	54	2 967	4,9	2,5	569 529	934	14,0	23,9	12,9
7	4,6	16	54	54	3 225	5,3	2,7	616 605	1 011	13,7	25,8	13,9
5	5,3	17	56	57	3 772	6,2	3,2	810 111	1 329	14,7	31,1	16,8
3	6,1	17	56	57	4 283	7,0	3,6	912 920	1 498	14,7	36,4	19,6
5/16"	7,9	19	58	60	5 557	9,1	4,7	1 313 751	2 155	15,5	46,1	24,5
3/8"	9,5	20	60	64	6 635	10,9	5,6	1 740 513	2 855	16,3	55,3	29,8

US Customary Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[in]	[in]	[in]	[in]	[in²]	[in²/in]	[in²/ft]	[in⁴]	[in⁴/in]	[in]	[lb]	[lb]
12	0,10	0,58	2,04	2,00	2,94	0,12	0,73	0,78	0,03	0,52	34,5	18,7
10	0,13	0,60	2,03	2,00	3,75	0,16	0,94	0,99	0,04	0,51	44,2	23,6
8	0,16	0,63	2,12	2,13	4,60	0,19	1,15	1,37	0,06	0,55	52,8	28,4
7	0,18	0,64	2,12	2,13	5,00	0,21	1,25	1,48	0,06	0,54	56,9	30,7
5	0,21	0,67	2,21	2,25	5,85	0,24	1,46	1,95	0,08	0,58	68,5	37,0
3	0,24	0,68	2,20	2,25	6,64	0,28	1,66	2,19	0,09	0,58	80,2	43,2
5/16"	0,31	0,73	2,27	2,38	8,61	0,36	2,15	3,16	0,13	0,61	101,6	54,0
3/8"	0,38	0,78	2,35	2,50	10,28	0,43	2,57	4,18	0,17	0,64	121,9	65,8

Permissible Safe Loads on Circular Tunnels of Various Diameters or Arches for 24" Wide Smooth Liner Plates [1)]

SI Units

Safe Load Table (Loads in [kN/m²])

Thickness [mm]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	2,66	3,42	4,18	4,55	5,31	6,07	7,94	9,53
Diameter [m]								
1,2 [2)]	208	310	380	414	485	552	720	864
1,5	166	248	304	331	388	441	576	691
1,8		205	253	276	323	368	480	576
2,1			197	214	272	309	412	494
2,4				150	199	227	325	420
2,7					141	161	238	319
3,0						117	173	236
3,4							130	177
3,7							100	136
4,0								107
4,3								86
4,6								
4,9								
5,2								
5,5								
5,8								
6,1								

US Customary Units

Safe Load Table (Loads in [psf])

Thickness [ft]	12 Gage	10 Gage	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	0,1046	0,1345	0,1644	0,1793	0,2092	0,2391	0,3125	0,375
Diameter [ft]								
4 [2)]	4 335	6 465	7 940	8 640	10 130	11 525	15 040	18 050
5	3 465	5 170	6 350	6 910	8 100	9 220	12 030	14 440
6		4 290	5 290	5 760	6 750	7 685	10 025	12 030
7			4 110	4 470	5 675	6 460	8 595	10 315
8				3 130	4 160	4 735	6 785	8 745
9					2 950	3 355	4 970	6 640
10						2 445	3 620	4 895
11							2 720	3 680
12							2 095	2 835
13								2 230
14								1 785
15								
16								
17								
18								
19								
20								

1) Note: 4-flange liner plates for tunnel diameters other than those shown in the tables are available. Please refer to DSI Underground engineering staff for a safe load determination outline.

2) Not recommended for circular tunnel applications.

Sectional Properties for 24" Wide Smooth Liner Plates

SI Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[mm]	[mm]	[mm]	[mm]	[mm²]	[mm²/mm]	[mm²/mm]	[mm⁴]	[mm⁴/mm]	[mm]	[kg]	[kg]
12	2,7	5	46	51	1 861	3,1	1,6	192 715	316	10,2	15,6	8,5
10	3,4	5	45	51	2 383	3,9	2,0	243 079	398	10,2	20,0	10,7
8	4,2	6	48	54	2 926	4,8	2,5	349 634	574	10,9	23,9	12,9
7	4,6	6	48	54	3 185	5,2	2,7	377 938	619	10,9	25,8	13,9
5	5,3	7	50	57	3 734	6,1	3,1	514 462	844	11,7	31,1	16,8
3	6,1	7	50	57	4 249	7,0	3,6	578 562	949	11,7	36,4	19,6
5/16"	7,9	8	52	60	5 545	9,1	4,7	857 853	1 408	12,4	46,1	24,5
3/8"	9,5	10	54	64	6 654	10,9	5,6	1 168 362	1 917	13,2	55,3	29,8

US Customary Units

Plate Thickness		Dimensions			Theoretical Area		Effective Area	Moment of Inertia		Radius of Gyration	Weight	
Gage	Decimal	X	Y	Side Flange							Full Plate	Half Plate
[–]	[in]	[in]	[in]	[in]	[in²]	[in²/in]	[in²/ft]	[in⁴]	[in⁴/in]	[in]	[lb]	[lb]
10	0,13	0,20	1,77	2,00	3,69	0,15	0,92	0,58	0,02	0,40	44,2	23,6
8	0,16	0,23	1,89	2,13	4,54	0,19	1,13	0,84	0,04	0,43	52,8	28,4
7	0,18	0,24	1,89	2,13	4,94	0,21	1,23	0,91	0,04	0,43	56,9	30,7
5	0,21	0,27	1,98	2,25	5,79	0,24	1,45	1,24	0,05	0,46	68,5	37,0
3	0,24	0,28	1,97	2,25	6,59	0,27	1,65	1,39	0,06	0,46	80,2	43,2
5/16"	0,31	0,33	2,04	2,38	8,59	0,36	2,15	2,06	0,09	0,49	101,6	54,0
3/8"	0,38	0,38	2,12	2,50	10,31	0,43	2,58	2,81	0,12	0,52	121,9	65,8
3/8"	0,38	0,78	2,35	2,50	10,28	0,43	2,57	4,18	0,17	0,64	121,9	65,8

Allowable Jacking Loads on Circular Tunnels of Various Diameters for 16" Wide Smooth Liner Plates [1)]

SI Units
Allowable Load [kN]

Thickness [mm]	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	4,18	4,55	5,31	6,07	7,94	9,53
Diameter [m]						
1,2	445	525	738	970	1 708	2 651
1,5	560	658	916	1 210	2 135	3 309
1,8	676	792	1 103	1 450	2 562	3 977
2,1	783	925	1 290	1 690	2 989	4 635
2,4	898	1 059	1 468	1 930	3 416	5 302
2,7	1 014	1 192	1 655	2 180	3 843	5 960
3,0	–	–	1 841	2 420	4 270	6 628
3,4	–	–	2 019	2 660	4 697	7 286
3,7	–	–	–	2 900	5 124	7 953
4,0	–	–	–	–	5 551	8 611
4,3	–	–	–	–	5 978	9 279
4,6	–	–	–	–	–	9 937
4,9	–	–	–	–	–	10 604
5,2	–	–	–	–	–	11 262

US Customary Units
Allowable Load in Short Tons (2 000 [lbs])

Thickness [ft]	8 Gage	7 Gage	5 Gage	3 gage	5/16"	3/8"
	0,1644	0,1793	0,2092	0,2391	0,3125	0,375
Diameter [ft]						
4	50	59	83	109	192	298
5	63	74	103	136	240	372
6	76	89	124	163	288	447
7	88	104	145	190	336	521
8	101	119	165	217	384	596
9	114	134	186	245	432	670
10	–	–	207	272	480	745
11	–	–	227	299	528	819
12	–	–	–	326	576	894
13	–	–	–	–	624	968
14	–	–	–	–	672	1 043
15	–	–	–	–	–	1 117
16	–	–	–	–	–	1 192
17	–	–	–	–	–	1 266

Allowable Jacking Loads on Circular Tunnels of Various Diameters for 24" Wide Smooth Liner Plates [1)]

SI Units
Allowable Load [kN]

Thickness [mm]	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	4,18	4,55	5,31	6,07	7,94	9,53
Diameter [m]						
1,2	356	418	560	712	1 165	1 744
1,5	454	516	703	890	1 459	2 180
1,8	543	623	845	1 068	1 753	2 615
2,1	632	729	979	1 245	2 037	3 042
2,4	721	827	1 121	1 423	2 331	3 478
2,7	–	–	1 263	1 601	2 624	3 914
3,0	–	–	–	1 779	2 918	4 350
3,4	–	–	–	–	3 203	4 786
3,7	–	–	–	–	3 496	5 222
4,0	–	–	–	–	–	5 658
4,3	–	–	–	–	–	6 094
4,6	–	–	–	–	–	–
4,9	–	–	–	–	–	–
5,2	–	–	–	–	–	–

US Customary Units
Allowable Load in Short Tons (2 000 [lbs])

Thickness [ft]	8 Gage	7 Gage	5 Gage	3 Gage	5/16"	3/8"
	0,1644	0,1793	0,2092	0,2391	0,3125	0,375
Diameter [ft]						
4	40	47	63	80	131	196
5	51	58	79	100	164	245
6	61	70	95	120	197	294
7	71	82	110	140	229	342
8	81	93	126	160	262	391
9	–	–	142	180	295	440
10	–	–	–	200	328	489
11	–	–	–	–	360	538
12	–	–	–	–	393	587
13	–	–	–	–	–	636
14	–	–	–	–	–	685
15	–	–	–	–	–	–
16	–	–	–	–	–	–
17	–	–	–	–	–	–

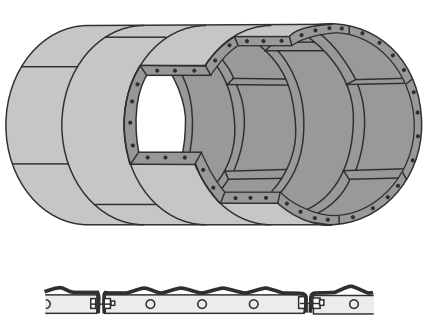
1) Note: 4-flange liner plates for tunnel diameters other than those shown in the tables are available. Please refer to DSI Underground engineering staff for a safe load.

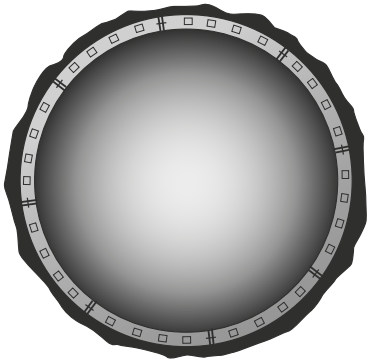
Advantages of 4-Flange Tunneling Liner Plates over conventional 2-Flange Liner Plates

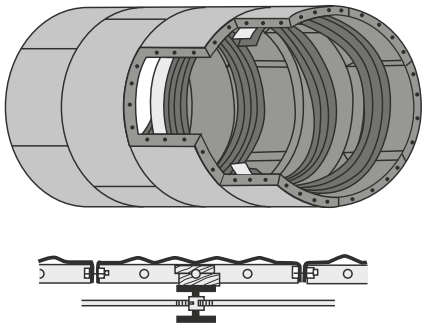
- All 4-flange liner plates are similar in size and shape, e.g. 2-flange plates vary considerably in length
- 4-flange liner plates are erected from inside the tunnel, whereas 2-flange plates require reaching behind the plates to install bolts and nuts
- 4-flange liner plates are the only liner plate system form which can be used to push off the liner plate flange with a TBM, MTBM, or shield without supplemental structural reinforcement
- Storage, manipulation, and erection of 4-flange liner plates requires less time and manpower
- Less excavation because 4-flange plates are only 50 to 65 [mm] (2 to 2 ½ [in]) deep while the deeply corrugated two-flange plates can be 100 to 125 [mm] (4 to 5 [in]) deep
- Less grout is used behind 4-flange plates because of the shallower corrugations versus the deeper 2-flange plates
- 4-flange liner plates are measured to the outside of plate while 2-flange plates are measured to the net neutral axis (NNA)

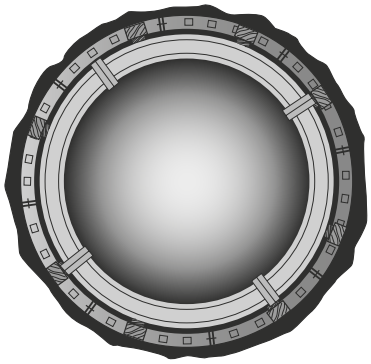
Liner Plate Support Types

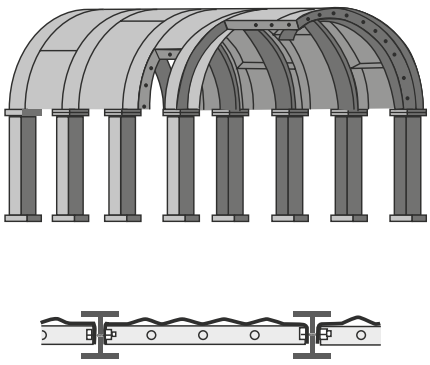
- Liner plates only
- Ribs inside liner plates
- Liner plates between ribs

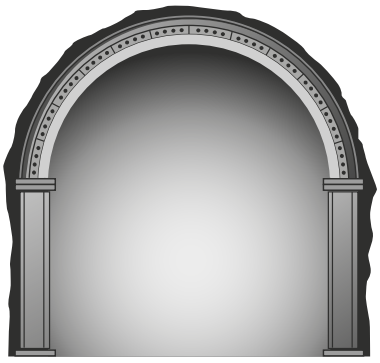












Installation Procedure

Introduction

Tunnels excavated by full face, heading and bench, or multiple drift procedures are considered conventional methods. Liner plates used with any construction method utilizing a full or partial shield, a tunneling machine, or other equipment which will exert a force upon the liner plates to propel, steer, or stabilize the equipment are considered special cases and are not covered by these specifications. In any case, liner plates must be assembled in accordance with the manufacturer's instructions.

Assembly

4-flange liner plates and all accessories required for erection must be transported to the point of installation in advance. Preferably, the unsupported section (span) in the excavation area is always kept at a minimum and complete liner plate rings are assembled at once. Full-face connection of 4-flange liner plates is accomplished using original bolts and nuts with quick acting coarse thread. The recommended procedure for bolt tightening is "turn of nut" per AISC (American Institute of Steel Construction).

Grouting

It is assumed that grouting is always performed to transfer ground loads to the 4-flange liner plates. Grout holes with plugs should be provided at a spacing sufficient to allow filling of all voids with grouting material. Grouting or backfilling should start at the lowest grout hole and proceed upward, preferably filling both sides of the tunnel simultaneously. The frequency of grouting depends on ground conditions, tunnel diameter, and total length.

Further References

- AASHTO Standard Specification for Highway Bridges, Division I, Section 16
- AREMA Manual for Railway Engineering, Section 4
- Recommendations from DSI Underground for the determination of loading on tunnel liner plates

LSC™ Elements

Introduction

Lining stress controllers (LSC™) have been developed as special supporting measure for Tunneling in zones with stress-induced failure involving large ground volumes and large deformations. The primary tunnel lining is divided into several segments by longitudinal construction joints. The purpose of this segmentation is the ability to absorb large deformations occurring during tunnel driving in weak ground.

LSC™ composite elements are installed into these deformation joints.
These elements have a defined workload during compression so the primary lining is not damaged.

DSI Underground has long-time experience in the application of LSC™ Elements, which have been successfully used for many projects.

Main Advantages

- Maintenance of supporting forces and optimum utilization of the load-bearing capacity of the primary lining
- Controlled stress release and deformability
- Steady increase of support resistance while undergoing large deformations
- Rapid increase of support resistance in slowly increasing deformations
- Avoidance of excessive tunnel liner overstressing
- Custom-specific adaptation of the deformation characteristics (force-shortening behaviour) of LSC™ Elements in accordance with project requirements
- The most effective lining stress controller currently used in Tunneling

System Description

Compared to the strength of the primary lining, the load-bearing resistance of LSC™ Elements is dimensioned at a lower level. Thus, large deformations can be absorbed by LSC™ Elements before the tunnel lining is damaged.
The optimum supporting effect is created by selecting the best suited LSC™ Elements and the proper number of compression bodies which determine the overall load-bearing resistance characteristics.

Single yielding elements are aligned between base plates. These plates fix the position of the yielding elements and limit LSC™ Elements towards the tunnel lining. Each yielding element has a factory-set imperfection where controlled deformations start in case of excessive loading. Base plates can be fitted with customized mounting or reinforcement bars.

System Components

- Base plates
- Yielding elements
  - Steel pipes with a defined material behaviour in combination with a porous filling material and a porous concrete inlay
- Mounting (reinforcement) bars

Specifications LSC™ N Elements

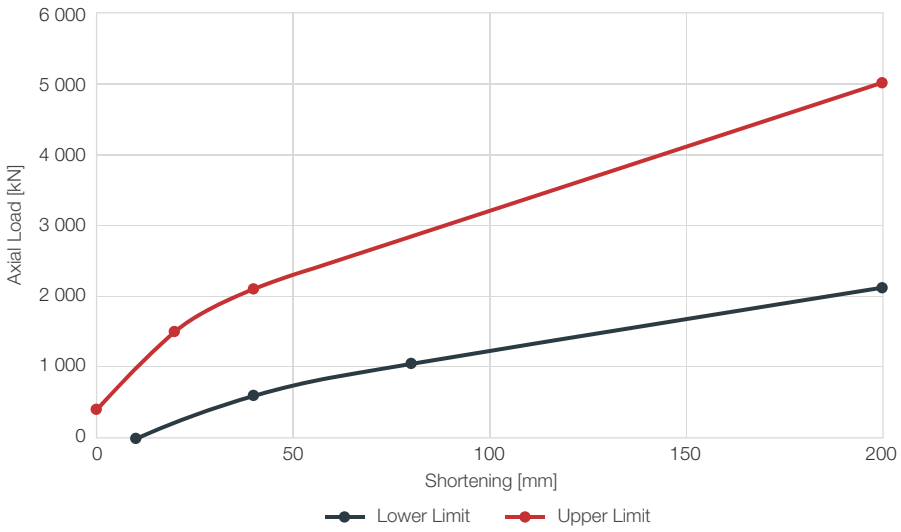
Characteristic [1]	Unit	Type	
Number of yielding elements	[–]	N 3	N 4
Length	[mm]	750 - 1 000	1 000 - 1 300
	[in]	29,5 - 39,4	39,4 - 51,2
Width	[mm]	250 - 350	
	[in]	9,8 - 13,8	
Height	[mm]	410	
	[in]	16,1	

1) Standard types for Tunneling. LSC™ N Elements with alternative dimensions available upon request.

Technical Characteristics

The type, quantity, and length of LSC™ N Elements is optimized to the load-bearing capacity of the primary lining and typical displacements measured at the tunnel wall

- Project-specific customization of the LSC™ Element geometry
- Load-deformation characteristics can be changed to permit an adaption of the support resistance
- Exemplary load-deformation characteristics of the LSC™ N system with three yielding elements (type 3) are defined with upper and lower limits as shown in the diagram



Background [1)]

Yielding elements have been a research topic at Graz University of Technology for years. Rabcewicz first introduced such a system in his dissertation “Die Hilfsgewoelbebauweise” in 1950, where he had the idea to integrate timber elements in the shotcrete lining to deal with the large amount of deformations, but this knowledge fell into oblivion for a long time so that no further research has been done.

At several tunnel construction sites in Austria a concept with open gaps was in use for a long time, until a collapse at the “Galgenberg Tunnel”. This event enforced Schubert et al. in 1996 to do some further development.
They introduced a system where single pipes are loaded in axial direction. A big disadvantage of this system was the high oscillation of the force-shortening curve. Moritz adapted the system in 1999, to obtain an increase in its bearing capacity and to reduce the oscillation of the force-shortening curve (System LSC™).

This system LSC™ has been refined by Sitzwohl in 2011, by Verient in 2014 and by Brunnegger in 2016 with a porous filling material and different inlays to obtain a smooth force-shortening behaviour and to decrease the initial stiffness. With this knowledge, the rearrangement of the system was finalized in 2016 to launch a new product on the market (System LSC™ N).

1) Source: Brunnegger (2018)

Rabcewicz
Hilfsgewoelbebauweise 1950

Schubert
Prototype 1996

Schubert & Moritz
LCS 1997

Schubert & Brunnegger
LCS-N 2017

Installation Procedure

– Installation of lattice girders and first layer of welded wire mesh

– LSC™ Element ready for installation

– Lifting up in position
– Mounting of a holding bar at the bottom

– Placement of LSC™ Elements onto the holding bar
– Connection of upper and lower reinforcement bars to lattice girders

– Coverage of LSC™ Elements with a wooden plank

– Ready installed LSC™ Elements

References

– Rabcewicz, L. v. 1950: Die Hilfsgewoelbebauweise. Graz University of Technology, Graz, Austria
– Schubert, W., Golser, J. and Schwab, P. 1996: Weiterentwicklung des Ausbaues für stark druckhaftes Gebirge. In: Felsbau 14, Nr. 1, p. 36-42.
– Moritz, B.: 1999 Ductile Support System for Tunnels in Squeezing Rock. PhD Thesis, Institute of Rock Mechanics and Tunnelling, Graz University of Technology, Graz, Austria
– Radončić, N., Schubert, W., Moritz, B. 2009: Ductile support design. In: Geomechanics and Tunnelling 2, No. 5, p. 561-577, Graz, Austria
– Schubert, W. et al 2017: Support aspects of tunnels in fault zones. In: Geomechanics and Tunnelling, Vol. 10, No. 4, Graz, Austria
– Brunnegger, S. 2018: Optimization of Yielding Elements. Master's Thesis, Graz University of Technology, Institute of Rock Mechanics and Tunnelling, Graz, Austria

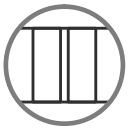
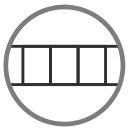
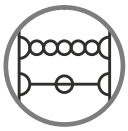
BULLFLEX® Support System

Introduction

The BULLFLEX® support system has been developed as a special supporting member for underground mining and Tunneling. It consists of patented textile groutable hoses made of high-strength fabric, which are subsequently filled with cement-bonded construction material, featuring a supreme load-bearing capacity.

The BULLFLEX® support system is available for different applications and in different dimensions, allowing an optimum alignment to respective excavation and support requirements.
All system components are lightweight and easy to transport and to install.

DSI Underground has long-time experience in the application of the BULLFLEX® support system, which has been successfully used for various projects.

		Hard Rock Mining	Soft Rock Mining	Mine Rehabilitation	Tunnel Rehabilitation	TBMs and Foundations
Support pillars		Auxiliary standing support, artificial pillars, and cornerslumps	Secondary support in room & pillar and longwall mining	Repair works in overstressed or fault zone areas and rehabilitation of visitor mines		–
Roof support backfilling and underpinning		Backfilling of steel support for permanent main roadways	Yielding support system – displacement minimization	Re-establishment of the load-bearing capacity and yielding ability of destructed tunnel linings	Foundation and prestressing of pipe umbrella support or rib support systems	Temporary steel frame support for the construction of cross-cuts
Roadway packs and dams		–	Multiple entry roadways, gaseous seams, and deep mining operations	–	–	–
Structural bulkheads		Sealing against backfilling media	Permanent sealing of roadways	Partition of storage or waste facilities		–
Stoppings		Ventilation walls, sealings, and face shuttering		–	–	–
Structural sealings [1]		–	–	–	Sealing of existing re-lined tunnels and annular gaps of civil structures	O-ring sealings: launch and receptions of TBMs, sealing against water (liquids) and compressed air

1) See separate catalogue section “BULLFLEX® Structural Sealings”.

Support Pillars: Soft Rock

Support Pillars: Hard Rock

Roof Support Backfilling

Underpinning

Roadway Packs and Dams

Structural Bulkheads

Stoppings

Special Solutions

System Description

The BULLFLEX® support system is used wherever a fast support solution is required. Due to active setting load and immediate load transfer, BULLFLEX® groutable hoses work like a strong hydraulic prop or competent bedding layer, which can be left in position as a permanent support.

BULLFLEX® groutable hoses are shrink-free because of their patented encasement – woven fabric hoses made of high-strength fabric.

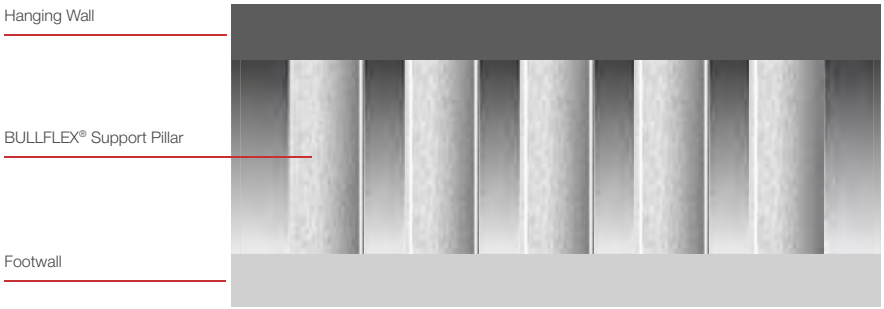
Depending on the required load and geometry, the BULLFLEX® support system can easily be adapted to on-site conditions using different diameters or filling material with varying compressive strength.

Main Advantages

- Fast and safe support system
- Immediate high load-bearing capacity and load transfer
- Active setting load and controlled residual load
- Flexible support characteristics thanks to different variations of groutable hose diameter and filling media
- Defined consumption of filling material
- Inflation can be achieved using different types of filling material
- Shrink-free
- Quick and easy to install
- Easy handling on-site due to lightweight components
- Application possible even in limited space conditions

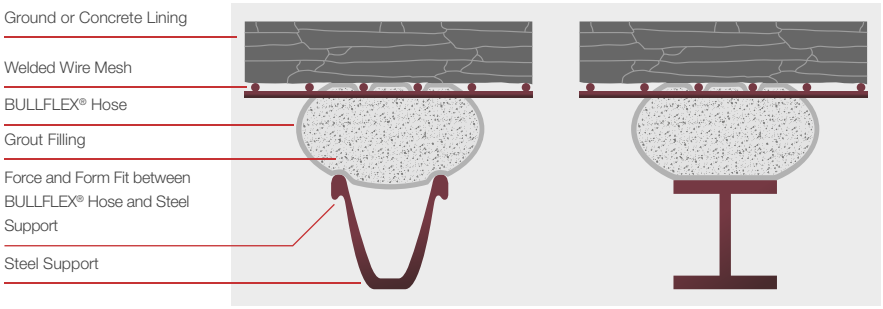
Support Pillars

- Active pre-loading feature
- Increase of safety support factor or extraction rate



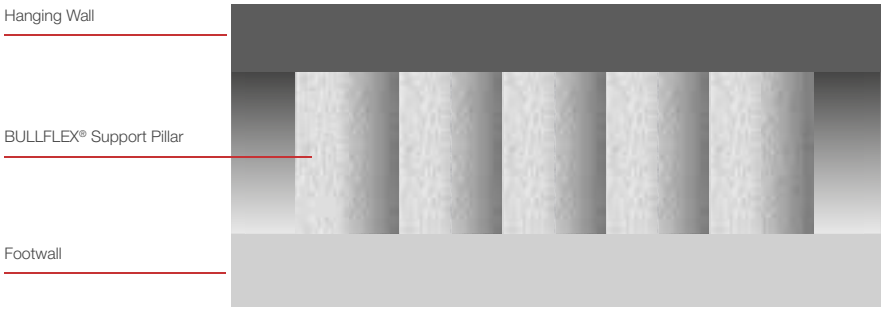
Roof Support Backfilling

- Full load distribution versus point loading
- Change from a passive to an active support system
- Full bedding of the steel profile leads to an enhanced utilization rate and may allow use of the next smaller profile type



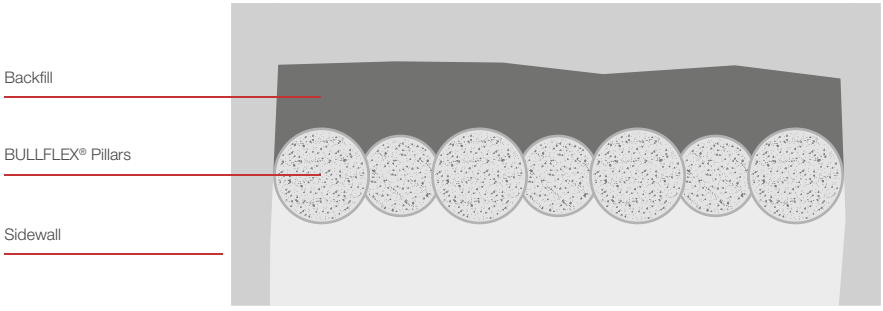
Roadway Packs and Dams

- Combined support and sealing system
- Flexible pillar height



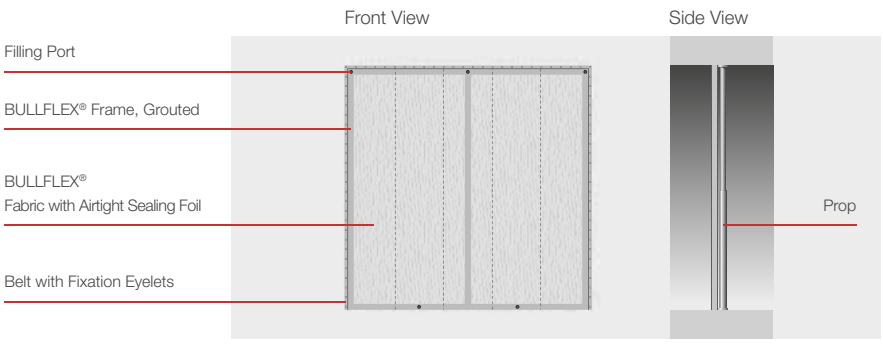
Structural Bulkheads

- Defined support system for backfilling applications
- Active vertical and horizontal prestressing



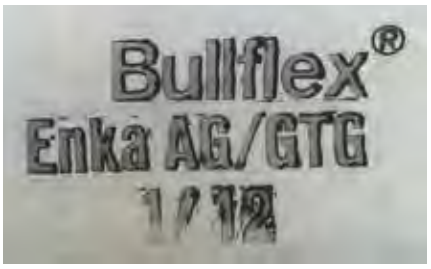
Stoppings

- Light and heavy duty versions
- Low weight and rapid installation



System Components

- BULLFLEX® groutable hoses
  - Endless round woven hoses made of polyamide 6,6
  - High resistance against tearing and no longitudinal seams
  - Anti-static, flame resistant, and self-extinguishing
  - Working pressure up to 4 [bar] (58 [psi])
  - Air and water permeable
  - Retention of the grout mineral content while draining due to the special filter effect of the BULLFLEX® system
  - Compliance with filter self rescuer systems
  - Off-size diameters and special designs are available upon request
  - Patented product technology

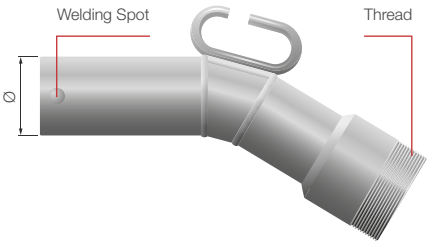


Application	Diameter		Length / Height	
[–]	[mm]	[in]	[m]	[ft]
Support pillars	280 - 960	11 - 38 [1)]	1,5 - 7,1	5 - 23
Roof support backfilling	230 - 400	9 - 16	Length as required	
Roadway packs and dams	480 - 960	19 - 38 [1)]	1,5 - 7,1	5 - 23
Structural bulkheads	280 - 960	11 - 38 [1)]	Length as required	
Stoppings	Flat fabric		Length as required	

1) Larger diameters available upon request.

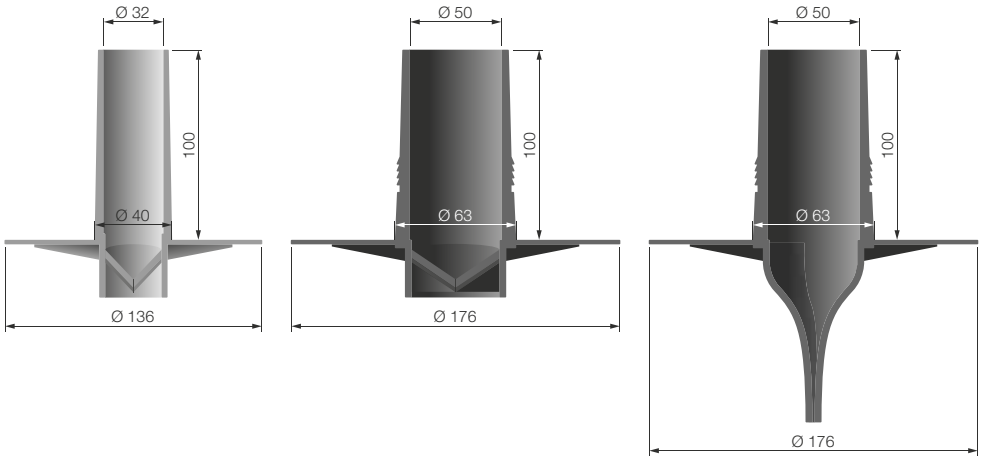
- BULLFLEX® filling ports
  - Pre-manufactured with integrated upper closure, filling port(s), and bottom plate
  - With check valve, inner diameter 32 [mm] (1¼ [in]) or 50 [mm] (2 [in])
  - Number of filling ports depending on the length/height of the BULLFLEX® groutable hoses
- BULLFLEX® filling nozzle
- BULLFLEX® multiple-use formworks
  - For installation of larger-size BULLFLEX® groutable hoses, multiple-use steel formworks are required
  - Stabilization and fixation during installation (inflation)
- Filling material
  - See table for recommended injection material

Filling Nozzle DN 32 / DN 50



Filling Port	DN 32	DN 50
Ø [mm]	28	45
Thread ["]	1 ¼	2

Filling Ports



DN 32 *DN 50* *DN 50 for Coarse Aggregates*

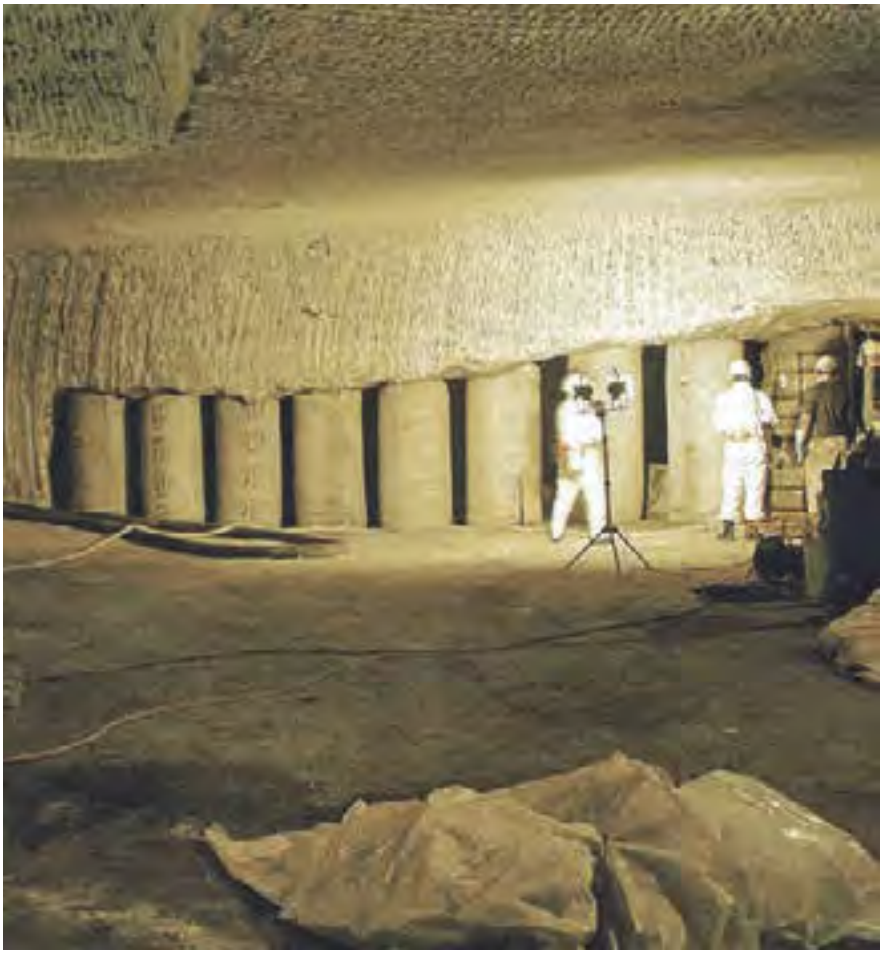
Specifications

Characteristic [1]		Unit	Value	Remarks
Material		[–]	Polyamide 6,6	Nylon
Weight		[g/m²] / [oz/yd²]	Approx. 660 / 19,5	–
Fabric thickness		[mm] / [in]	Approx. 1 / 0,04	–
Minimum tensile strength	L [2] T [3]	[N] / [lbf]	12 000 / 2 698 24 000 / 5 395	100 [mm] / 3,94 [in] width According to ISO 10319
Corresponding maximum elongation	L [2] T [3]	[%]	20 20	According to ISO 10319
Elastic elongation	L [2] T [3]	[%]	15 15	According to ISO 10319
Minimum seam strength		[kN/m] / [lbf/ft]	155 / 113	–
Airflow through fabric at pressure [mbar] ([psi])	10 (0,15) 20 (0,30) 30 (0,45)	[L/min] / [gal/min]	6,5 / 1,7 13 / 3,4 19 / 5,0	At 100 [cm²] / 15,5 [in²]
Residual tensile strength		[%]	20 - 30	After 1 year and under light exposure in Florida

1) The indicated values are laboratory values and may deviate on-site.

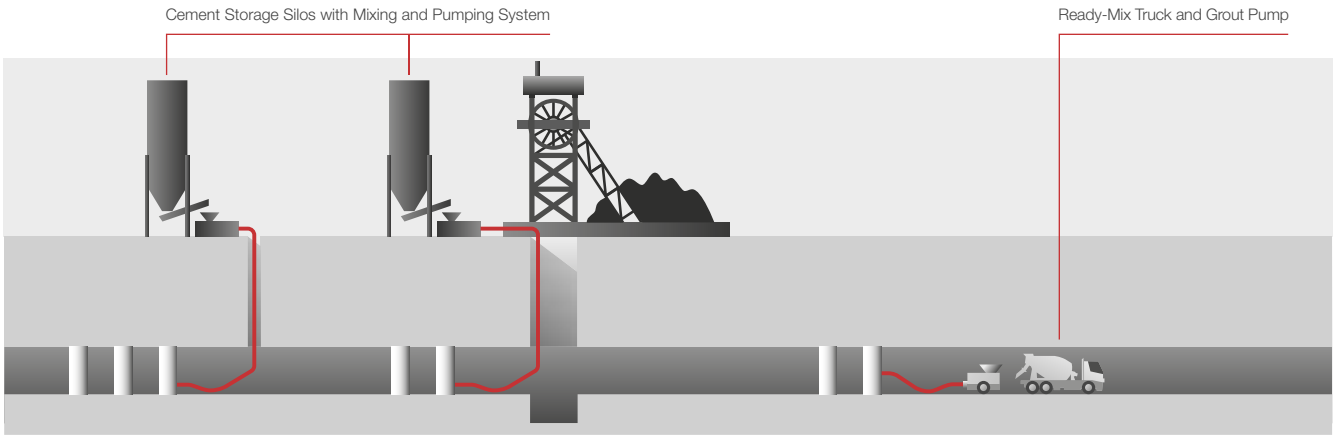
2) Longitudinal.

3) Transversal.



Material Logistics, Pumping, and Mixing Equipment

Two Concepts for Optimum Installation Performance



Recommended Injection Material [1)]

Characteristic	Unit	Value	Remarks
Composition	[%]	25 - 50% portland cement 75 - 50% fly ash	Alternatively, stone powder or a mixture of fly ash and sand can be used instead of fly ash [2)]
Compressive strength after 1 day	[N/mm²] / [psi]	> 2 / > 290	EN 196 / ASTM C1019
Compressive strength after 28 days	[N/mm²] / [psi]	> 25 / > 3 630	EN 196 / ASTM C1019
Slump class	[–]	Medium-high	EN 12350-5 / ASTM C143
Max. grain size	[mm] / [in]	3,8 / 0,15	Default aggregate grading curve
W/C ratio	[1]	0,7 - 0,9	–
Setting time	[min]	30 - 120	–

1) Further references: ASTM C1107; ASTM C827; ASTM C143; EN 1045; EN 206-1.

2) Aggregates should not have constituents harmful to concrete.

Main Factors Affecting the Workability of the Injection Medium

- Water-cement ratio
- Amount and type of aggregate and cement
- Ambient temperature
- Chemical admixtures

Requirements Pumping and Mixing Equipment

- Application of either a separate mixing and pumping unit, or a combined mixing/pumping device
- Pumpable with standard worm pumps for flooring or injections works with a nominal power of 7,5 to 12 [kW] and a minimum flow rate of 20 [L/min] (5 [gal/min])
- Default filling rates should be in the range of approx. 80 - 180 [L/min] (21 - 48 [gal/min])

Recommendations for Installation

- Ensure that injection hoses are laid out without kinks, avoid contact with any sharp edges in order to prevent the fabric from being damaged
- Wherever there is a change of direction, the bending radius must be greater than six times the outside hose diameter
- Screw pumps are high-pressure pumps, therefore only steel-reinforced hoses may be used for grout transport
- Before starting the machine, ensure that easily workable grout is being used
- The intake hose must not leak anywhere (especially not at connections), and the inner side of the hoses must be sufficiently lubricated

Support Pillars

Standard Dimensions [1)]

Designation	Hose Diameter		Inflated Groutable Hose	
[–]	[mm]	[in]	[mm]	[in]
9 - 11"	230	9	280	11
13 - 15"	320	13	380	15
16 - 19"	400	16	480	19
20 - 23"	500	20	590	23
25 - 29"	630	25	740	29
31 - 38"	800	31	960	38

1) Intermediate and larger diameters available upon request.

Characteristics

Pillar Diameter [1)]		Max. Recommended Pillar Height [2)]		Active Pre-Loading [3)]		Injection Material Consumption [4)]		Average Inflation Time [4)]
[mm]	[in]	[m]	[ft]	[kN]	[kip]	[m^3]	[ft^3]	[sec]
480	19	3,6	12,0	100	22	0,2	7,0	85
590	23	4,4	14,5	150	34	0,3	10,5	125
740	29	5,2	17,0	240	54	0,4	14,0	200
960	38	7,1	23,5	400	90	0,7	24,5	330

1) Other dimensions available upon request.

2) At a slenderness ratio of 30, rounded.

3) Calculated at a filling pressure of 4 [bar] (58 [psi]) and for two contact areas (hanging wall and footwall), rounded.

4) Calculated for 1 [m] (3,3 [ft]) pillar height and at a flow rate of 130 [L/min] (34,5 [gal/min]), rounded.

Installation Procedure

1. At the pillar position, gravel and boulders must be removed from the footwall. If possible, the footwall area should be horizontal or parallel to the incline of the hanging wall.
2. For support pillars ≥ 3 [m] (10 [ft]): subsequent mounting of the temporary or permanent formwork, which should reach up to a height of approx. 200 [mm] (8 [in]) below the hanging wall. Placement of the fabric into the formwork and fixation by loops attached to the fabric.
3. For support pillars < 3 [m] (10 [ft]): installation without formworks; the fabric is fixed to the hanging wall by mounting lashes. Afterwards, outside straps are cut open so the support pillar can unfold.
4. Inflation of the BULLFLEX® pillar through the filling port using the filling nozzle until full contact with the roof has been established. Check that the pillar inflates correctly and develops the desired shape.
5. Increase of the filling pressure up to 4 [bar] (58 [psi]) to achieve active pre-loading. Once the rated filling pressure has been reached, wait for approx. 3 minutes. Then, continue to apply until a pressure of 4 [bar] (58 [psi]) has been reached again. Real test: the BULLFLEX® pillar should have a thumb pressure compared to a bicycle tire.
6. If a temporary formwork has been used, it may be removed as soon as the concrete filling has reached a curing strength of 5 [N/mm²] (725 [psi]) and then may be re-used for setting the next pillar.

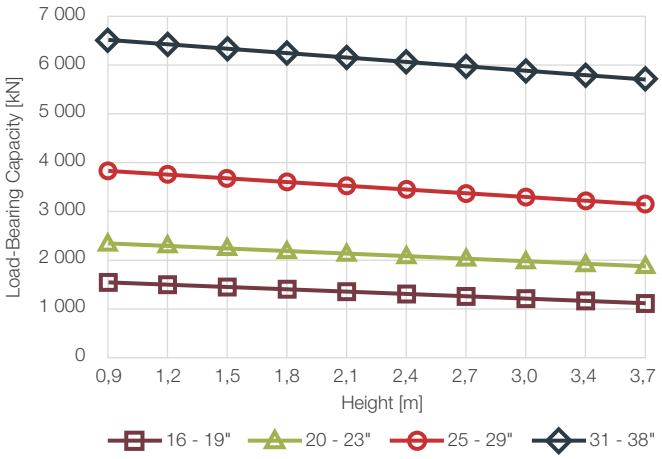
Note: during inflation (cement injection), all default and recommended personal protective equipment must be used. BULLFLEX® pillars are resistant against mine water inflow; the fabric itself is only soluble in concentrated inorganic acids and phenol.

Load-Bearing Capacity

SI Units

Type	Height [m] and Load-Bearing Capacity [kN]				
[in]	0,9	1,2	1,5	1,8	2,1
16 - 19"	1 570	1 522	1 474	1 427	1 379
20 - 23"	2 412	2 353	2 295	2 236	2 178
25 - 29"	3 850	3 777	3 703	3 630	3 556
31 - 38"	6 564	6 469	6 374	6 279	6 183

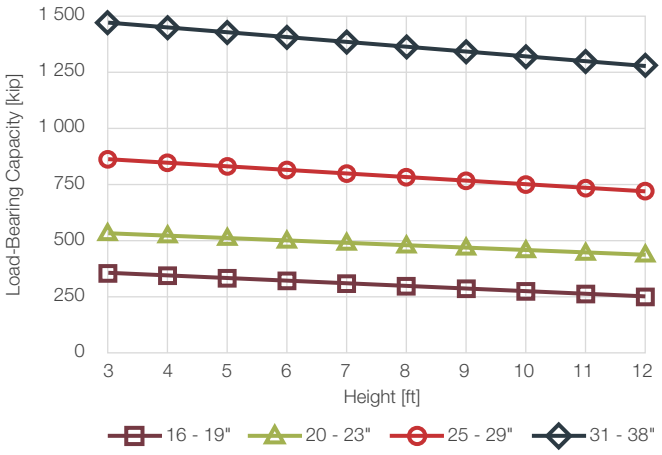
Type	Height [m] and Load-Bearing Capacity [kN]				
[in]	2,4	2,7	3,0	3,4	3,7
16 - 19"	1 332	1 284	1 236	1 189	1 141
20 - 23"	2 119	2 061	2 002	1 943	1 885
25 - 29"	3 483	3 409	3 336	3 263	3 189
31 - 38"	6 088	5 993	5 898	5 802	5 707



US Customary Units

Type	Height [ft] and Load-Bearing Capacity [kip]				
[in]	3	4	5	6	7
16 - 19"	353	342	331	321	310
20 - 23"	542	529	516	503	490
25 - 29"	866	849	833	816	799
31 - 38"	1 476	1 454	1 433	1 412	1 390

Type	Height [ft] and Load-Bearing Capacity [kip]				
[in]	8	9	10	11	12
16 - 19"	299	289	278	267	257
20 - 23"	476	463	450	437	424
25 - 29"	783	766	750	733	717
31 - 38"	1 369	1 347	1 326	1 304	1 283



- Load-bearing capacity depending on pillar height, calculated
- Without consideration of active setting load
- Calculation basis for pre-dimensioning, including factors of safety
- Actual in-situ load-bearing capacity determined by static load tests, exceeding the stated values
- Examined in the course of a static load test series at the NIOSH ground control laboratories (Pittsburgh, US-PA)
- Project-specific design proposals available upon request

Roof Support Backfilling

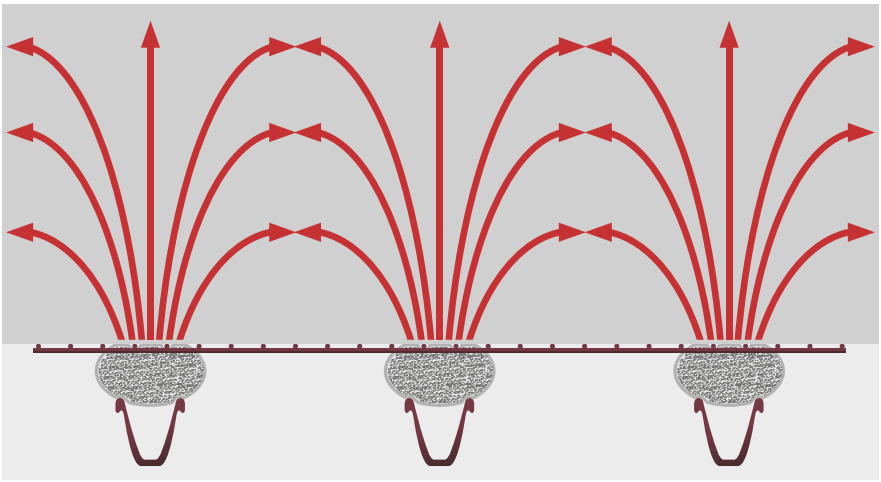
Standard Dimensions [1)]

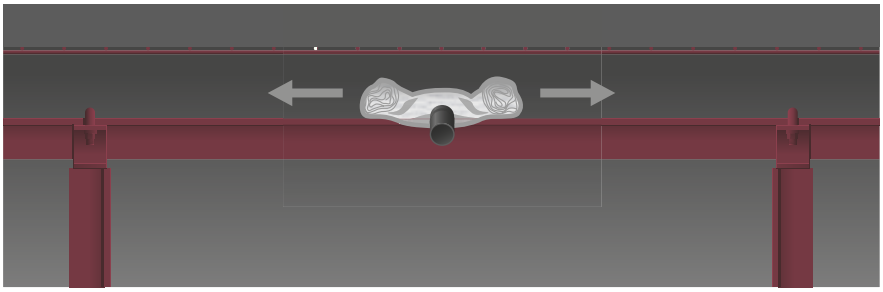
Designation	Hose Diameter		Inflated Groutable Hose	
[–]	[mm]	[in]	[mm]	[in]
9 - 11"	230	9	280	11
13 - 15"	320	13	380	15
16 - 19"	400	16	480	19

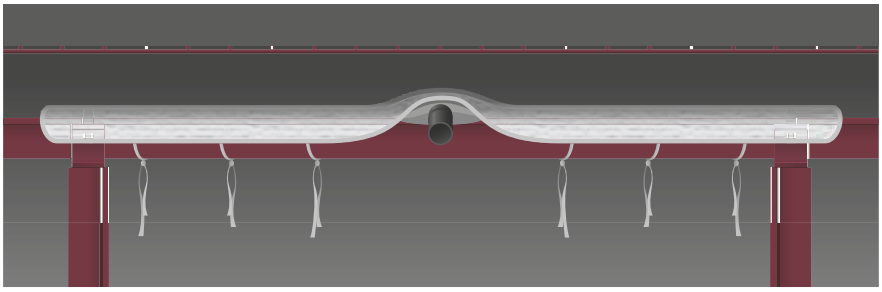
1) Intermediate and larger diameters available upon request.

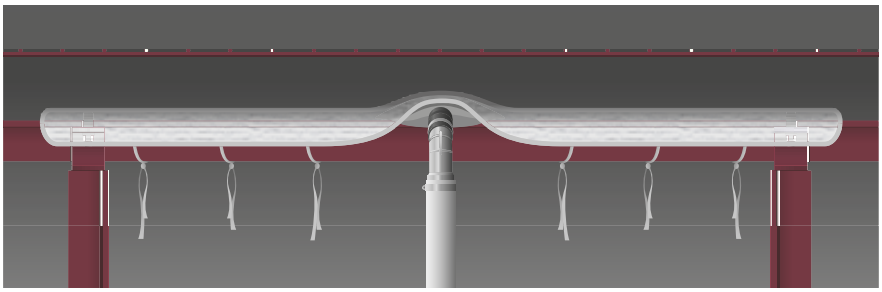
Transformation Point-Load to Full-Surface Support Action

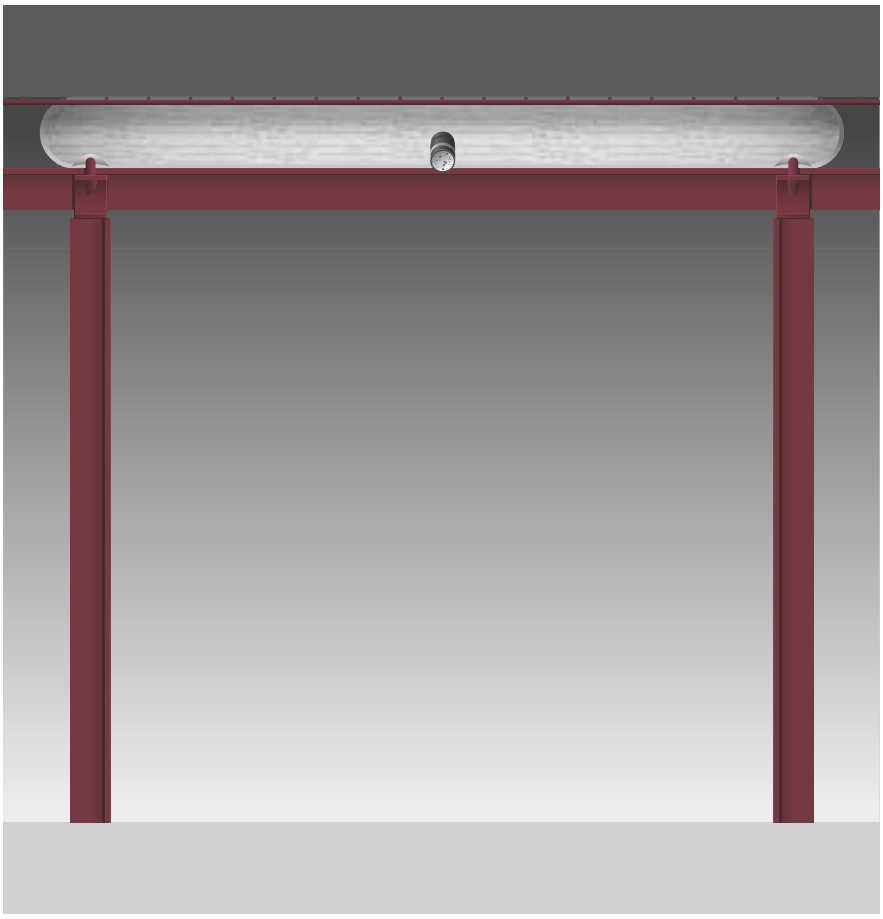
- Conventional steel support features a point-load transfer only
- Application of BULLFLEX® roof support backfilling enables a full-surface support action
- Support beams become a fully embedded and stiff system
- Optimized support action prevents further ground loosening and progressive block failure









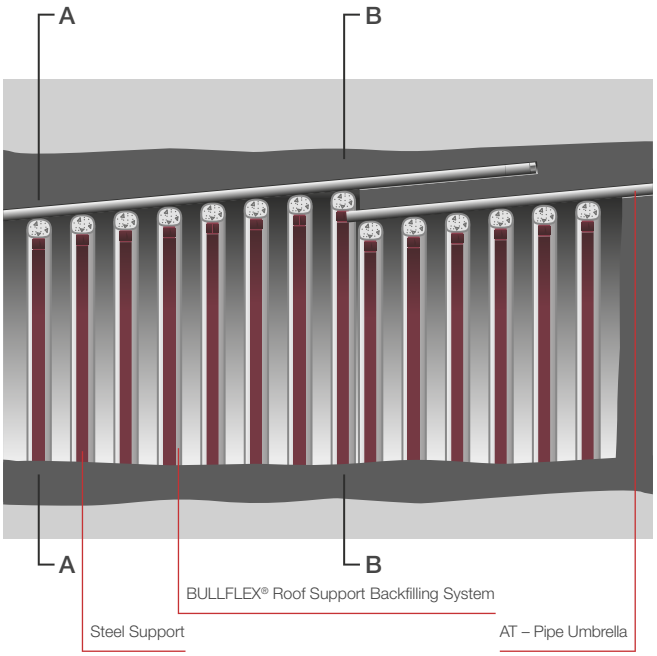


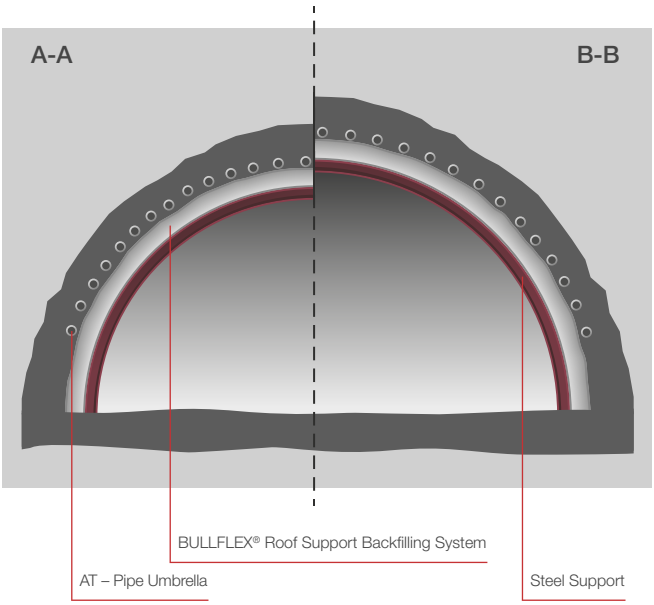
Installation Procedure

1. Keep the steel support in the installation area clean and free of sharp edges. BULLFLEX® roof support backfilling hoses are delivered coiled oppositional from both ends.
2. The oppositional coiled hose is laid on top of the steel support. Filling ports point in the direction of the tunnel entrance. Then, BULLFLEX® roof support backfilling hoses are rolled down to both sides.
3. BULLFLEX® roof support backfilling hoses are fixed onto the steel support with provided and integrated lashes.
4. Filling nozzles attached to grout hoses are inserted into filling ports and fixed by a clamp. If BULLFLEX® roof support backfilling hoses are equipped with more than one filling port, the filling procedure starts at the bottom ones. Note that the BULLFLEX® roof support backfilling hose correctly inflates and develops the desired shape.
5. Filling material is injected into all filling ports until a pressure of 4 [bar] (58 [psi]), measured at the filling point, is reached. Then wait for approx. 3 minutes. Then, continue to apply until a pressure of 4 [bar] (58 [psi]) has been reached again. Real test: the BULLFLEX® roof support backfilling hose should have a thumb pressure compared to a bicycle tire.

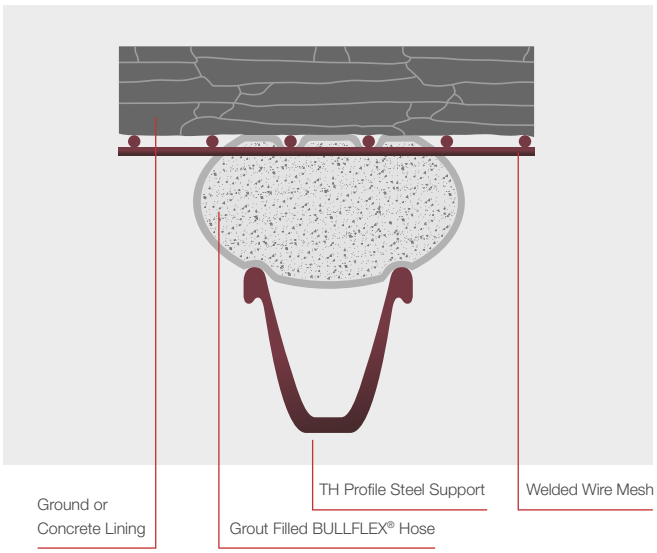
Note: during inflation (cement injection), all default and recommended personal protective equipment must be used. BULLFLEX® roof support backfilling hoses are resistant against mine water inflow; the fabric itself is only soluble in concentrated inorganic acids and phenol.

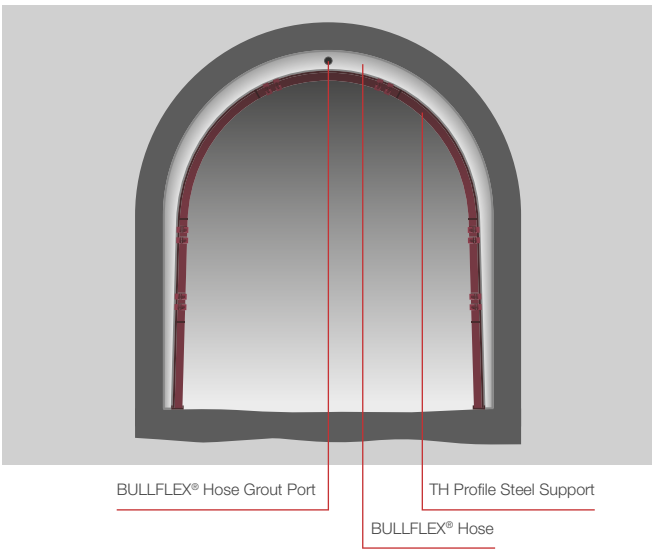
Tunneling





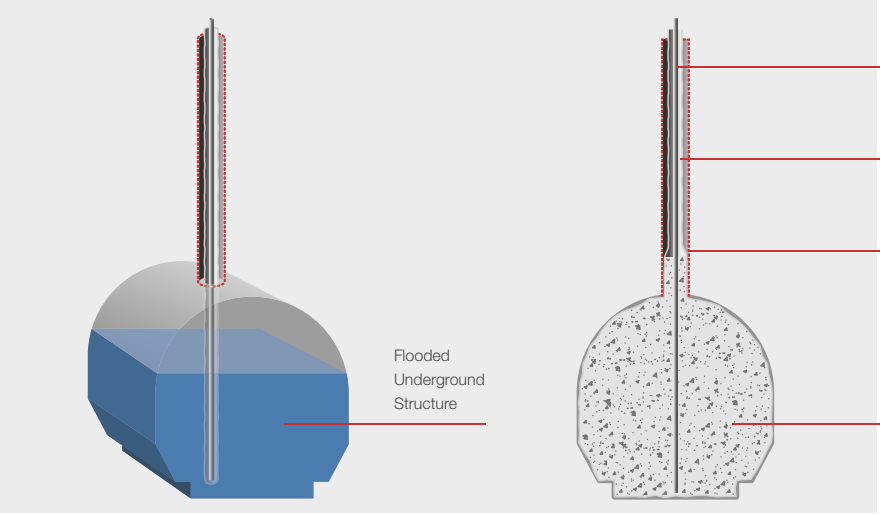
Mining





Nitschke et al. (2015)

Technical Barriers – Tunnel Plugs for Flooded Underground Structures



Installation Procedure

1. Drilling of a cased borehole from the surface down into the flooded tunnel area.
2. Insertion of a BULLFLEX® groutable hose into the borehole reaching from the surface down to the bottom of the tunnel cross section.
3. Filling of the BULLFLEX® tunnel plug with grout to replace the water.

Artificial Pillars

Mine Rehabilitation – Safekeeping Measures

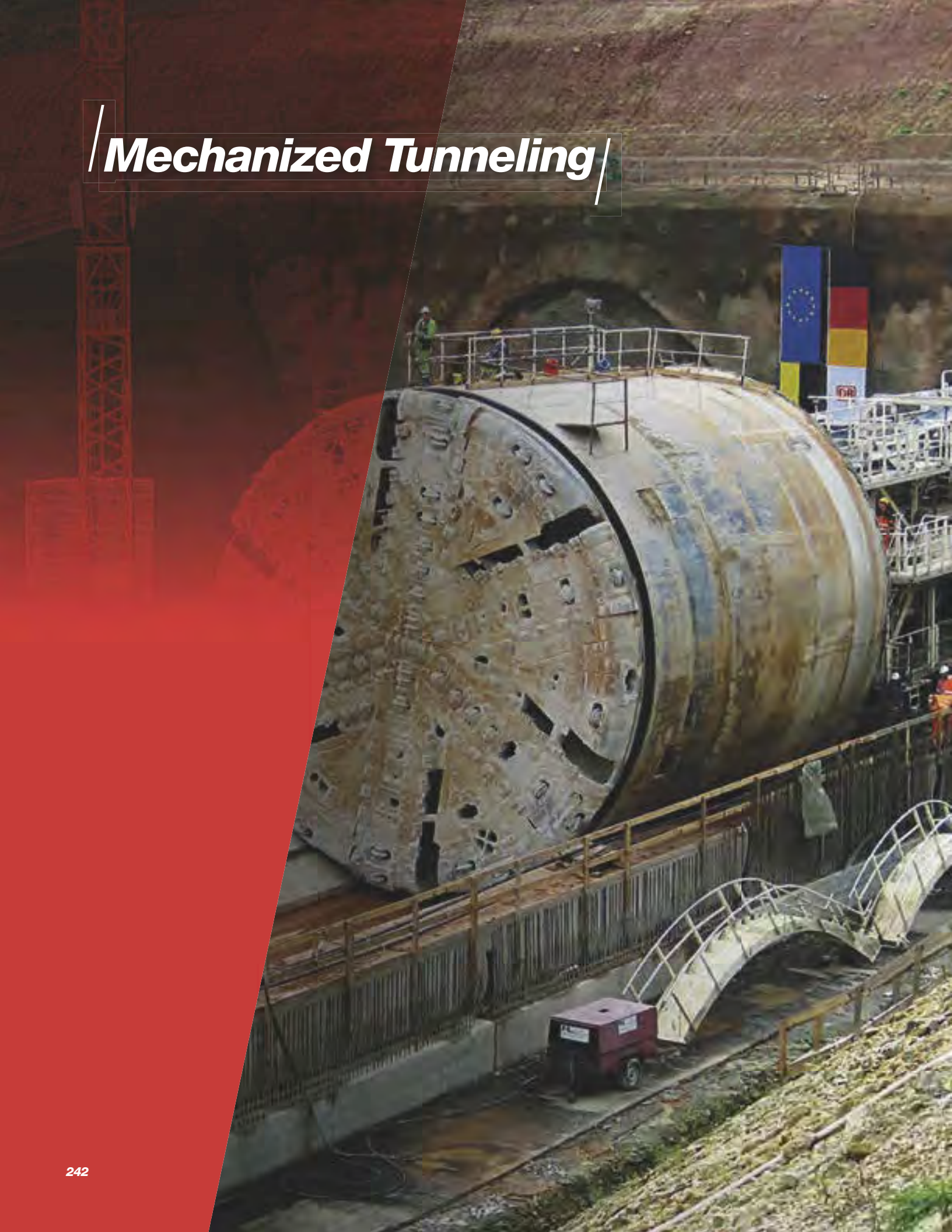
Bracing Cushions

Leveling Caissons

Further References

- Van Zanten, R. V.: Geotextiles and Geomembranes in Civil Engineering. A.A. Balkema. Rotterdam/Boston, 1986. ISBN 90 6191 6240. Page 156 ff.
- Safe application of mine roadway support systems. Rock Mechanics Technology Ltd, 2004. ISBN 0 7176 2847 7
- Breinig, F., Opolony, K.: Geplante Doppelnutzung einer Rechteckankerstrecke in 1200 m Teufe im Floez D2/C. Martens, P.N. (ed): Aachen International Mining Symposia 2004. Glueckauf, Essen, 2004. Page 159 ff.
- Declaration of conformity and material data sheets
- German approval for underground application (No. 18.43.21-61-40)
- British COAL acceptance scheme (No. NMM 5318) for the use of the material (fabric) as underground support element
- Nitschke, A.G. et al.: Innovative Rehabilitation of Existing Tunnels Under Minimum Impact on Operation. 2015 SME Annual Meeting, Preprint 15-131, February 2015

Mechanized Tunneling



Contents

Introduction

In accordance with global state-of-the-art methods in Tunneling, conventional (NATM/SEM) and mechanized excavation are the most common ones.

DSI Underground has always put a focus on the special demands in mechanized Tunneling and is now able to provide a comprehensive portfolio of ground control solutions which ensure a safe and efficient excavation.

Depending on the excavation type and given ground conditions, mechanized Tunneling goes along with project-specific requirements on ground control systems, excavation technology, and occupational safety.

Main requirements are as follows:

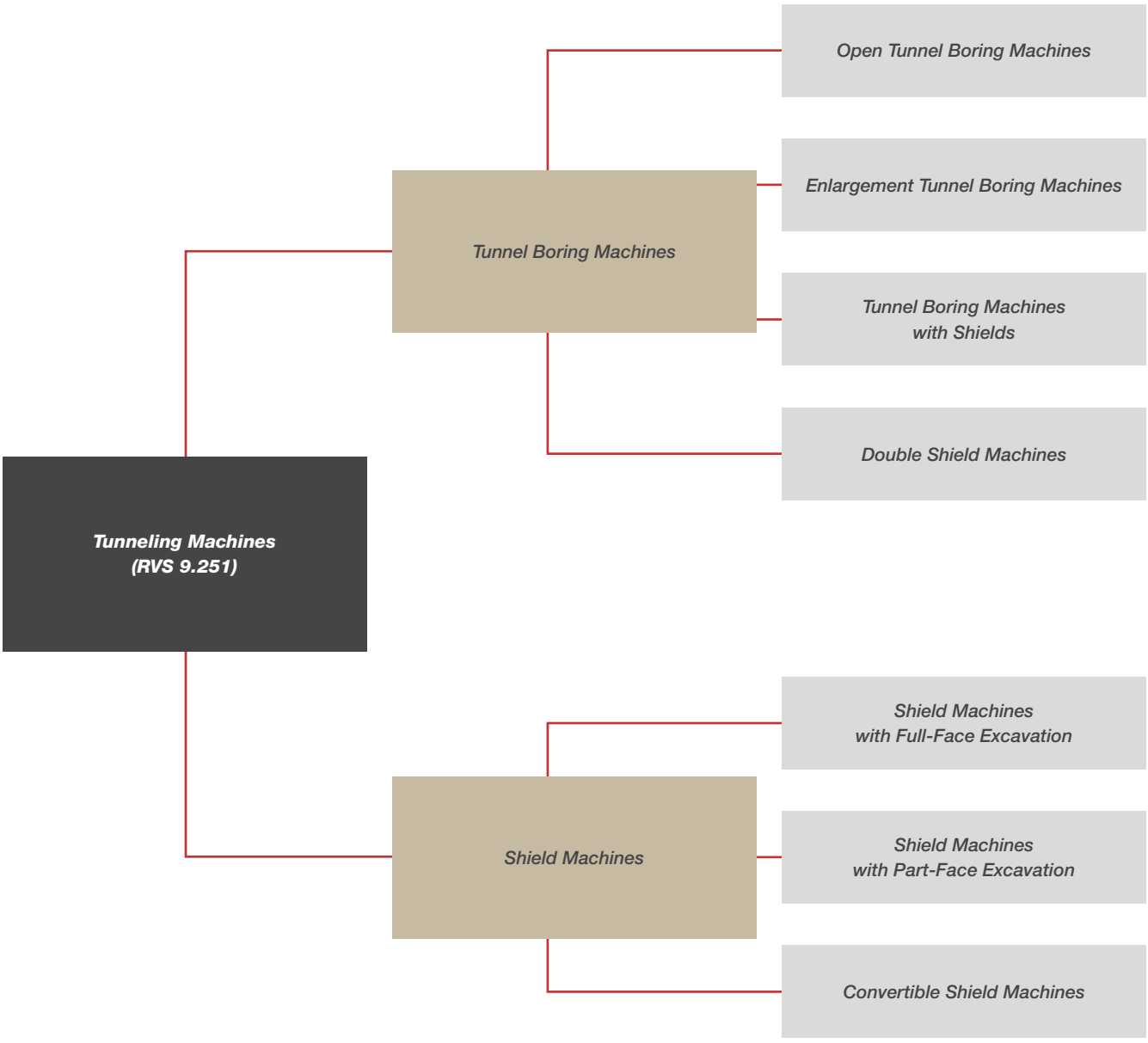
- Stabilization of the excavation perimeter during driving
- Filling and sealing of cavities
- Sealing against water inflow
- Flexible adjustments with regards to changes in ground conditions
- Pre-support measures in the area of fault zones
- Stabilization and protection of the Tunneling machine
- Minimization of displacements in urban areas

Basically, Tunneling machines are classified into tunnel boring machines (abbreviation TBMs) and shield machines (SMs). TBMs are mainly used for principle hard ground and SMs for principle soft ground conditions.

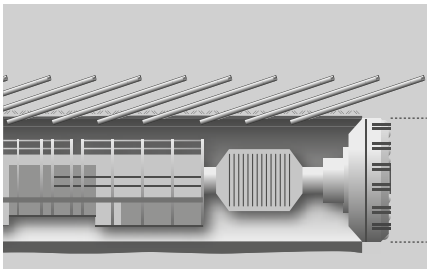
A safe and economically feasible implementation of each construction project always has the highest priority. Both in conventional and mechanized Tunneling, innovative and high quality ground control systems are key.

Besides decades of expertise, DSI Underground offers the widest product range available on the market.

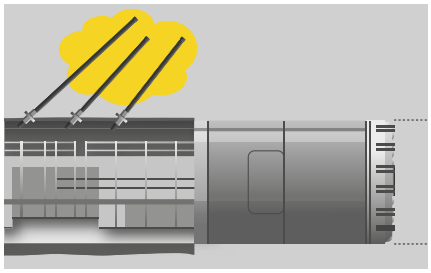
- Segmental lining
  - BULLFLEX® structural sealings
- Chemical injection and sealing solutions
  - AT – GRP Injection System
  - DSI Hollow Bar System
  - GRP injection lances
  - DSI Inject Systems
- Passive steel support
  - Liner plates
  - Ribs
- Forepoling systems
  - DSI Hollow Bar Spiles
  - AT – TUBESPILE™
  - AT – Pipe Umbrella Support System
- Bolts
  - DSI Hollow Bar System
  - OMEGA-BOLT® expandable friction bolts
  - POWER SET S-D friction bolts
  - GRP bolts
  - Mesh
- Equipment
  - Attachment units for semi or fully mechanized installation of ground control solutions
  - Grouting, injection, and backfilling pumps
  - Injection flow-pressure meters and injection data loggers



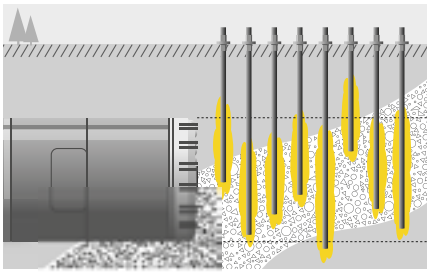
Fields of Application



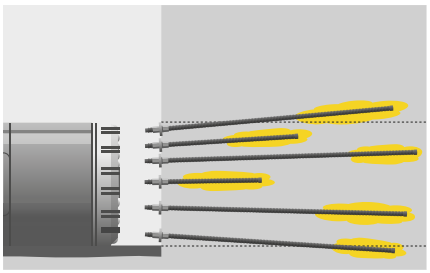
Forepoling
- DSI Hollow Bar System
- AT – TUBESPILE™



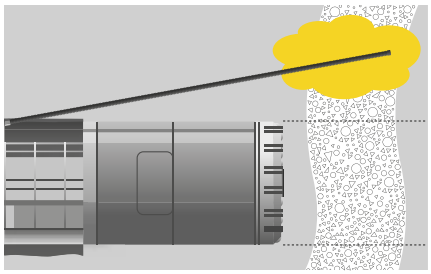
Filling of Cavities
- DSI Inject Systems
- GRP injection lances



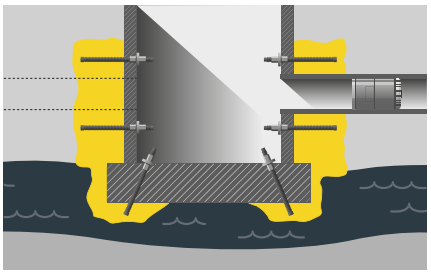
Ground Stabilization
- DSI Inject Systems
- GRP injection lances



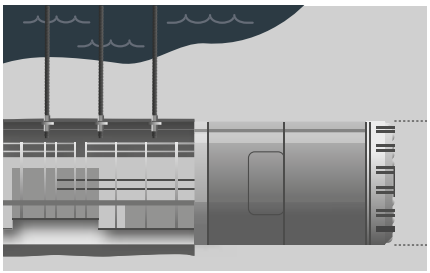
Soft Eyes and Cross-Cuts
- GRP Bolts
- DSI Inject Systems



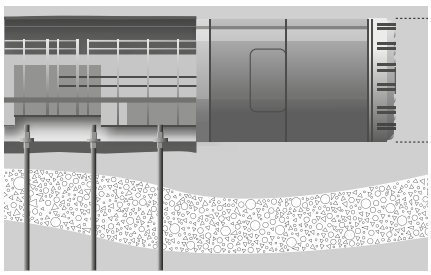
Fault Zone Consolidation
- AT – GRP Injection System
- DSI Inject Systems



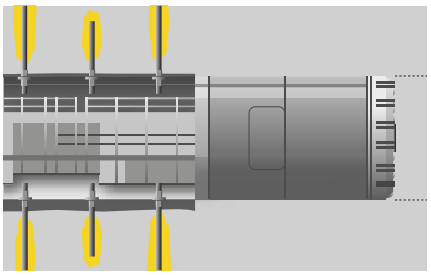
Sealing against Water
- DSI Inject Systems



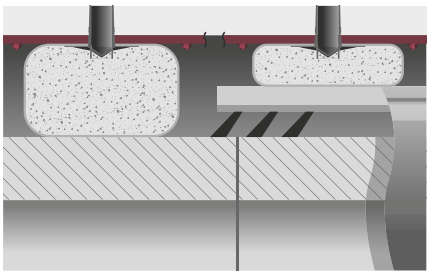
Drainage
- AT – Drainage System
- AT – TUBESPILE™ Vacuum Lances



Micropiles
- DSI Hollow Bar System
- AT – Pipe Umbrella System



Radial Injection
- DSI Hollow Bar System
- DSI Inject Systems



BULLFLEX® Structural Sealings
- O-ring sealing membrane, installed in the annulus between lining segment rings and outer shell or ground
- Sealing against water (liquids) and compressed air
- Launch and receptions of tunnel driving machines
- Sealing or re-lining of existing tunnels
- Sealing of annular gaps in civil structures
- Protection and stabilization of the cutterhead during a repair process

AT – GRP Injection System
- Ground improvement combined with mechanical excavation
- Waterproofing measures near openings and excavations
- Waterproofing measures in water-bearing fault zones

BULLFLEX® Structural Sealings

BULLFLEX® structural sealings have been developed as a special solution for underground construction. The main application of this system are o-ring sealing systems used in combination with tunnel boring machines (TBM's). They consist of patented textile groutable hoses made of high-strength fabric, which are subsequently filled with cement-bonded construction material featuring a supreme load-bearing capacity.

BULLFLEX® structural sealings are available in different dimensions, allowing an optimum alignment to excavation and machine dimensions. All system components are lightweight as well as easy to transport and install.
DSI Underground has long-time experience in the application of BULLFLEX® structural sealings. With the technical expertise and on-site support of DSI Underground, this system solution has been successfully used for various global infrastructure projects.

System Description

BULLFLEX® structural sealings are used wherever a fast o-ring solution is required. Their application ensures the protection of machinery and civil structures against flushing media, compressed air, water, and building materials. Each BULLFLEX® structural sealing is customized for its application, backed up with extensive global experience and engineering solutions.

Thanks to the special filter effect of the endless, patented BULLFLEX® fabric, the surplus water in the grout fill is immediately drained, providing an accelerated curing procedure. Hence, the pressure inside the BULLFLEX® system is maintained, inducing an active pre-load into the excavation perimeter which leads to an immediate sealing action.

Due to active setting load and immediate load transfer, BULLFLEX® groutable hoses work as a competent bedding layer. The BULLFLEX® system can easily be adapted to on-site conditions using different diameters or filling material.

BULLFLEX® structural sealings can be used for various applications such as:

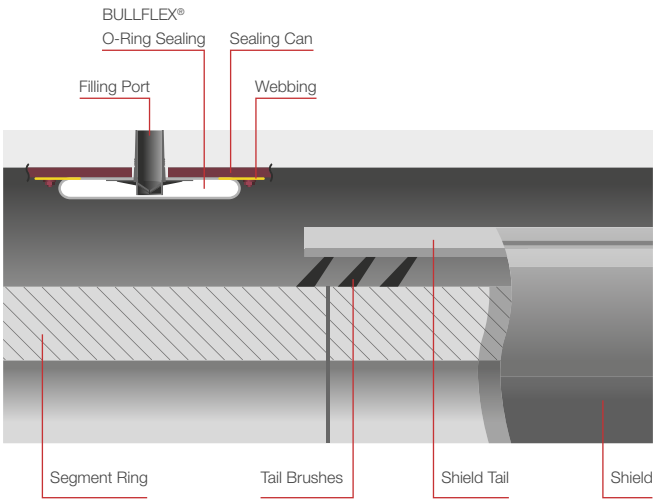
- O-ring sealing can/segment
- O-ring sealing can/shield
- O-ring sealing can/ground
- O-ring sealing pipe jacking
- Hose-in-hose o-ring sealing can/shield and can/segment
- Emergency sealing
- Segmental sealing

Main Advantages

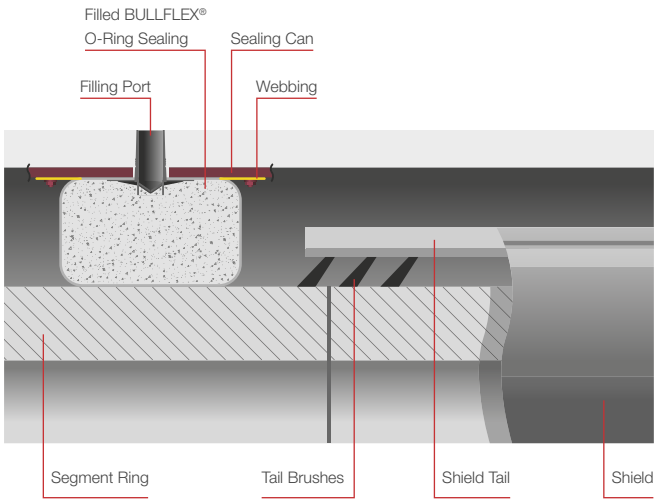
- Quick and easy to install
- Easy compensation of eccentric and uneven excavation surfaces
- Proven safety against failure of the sealing function in all working phases during passing-by of the TBM
- Application possible even in limited space conditions
- Special hose-in-hose system for TBM launching applications
- Easy handling on-site due to lightweight components
- High resistance against tearing
- No longitudinal seams
- Inflation can be achieved using different types of filling material
- Shrink free

System Solutions

O-Ring Sealing Can/Segment

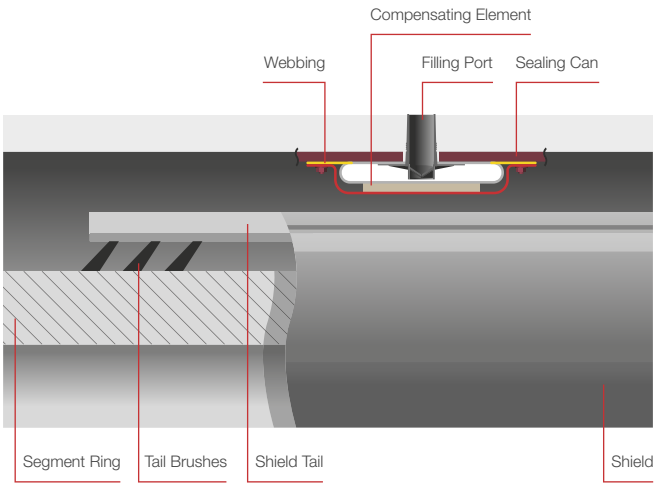


– Phase 1: the TBM shield has passed by the sealing can

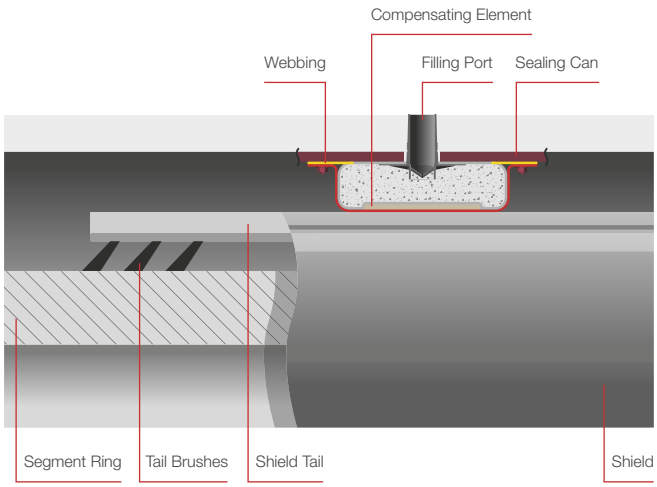


– Phase 2: activation of the BULLFLEX® o-ring sealing
– Minimization of leakages (water or irrigation fluids)

O-Ring Sealing Can/Shield



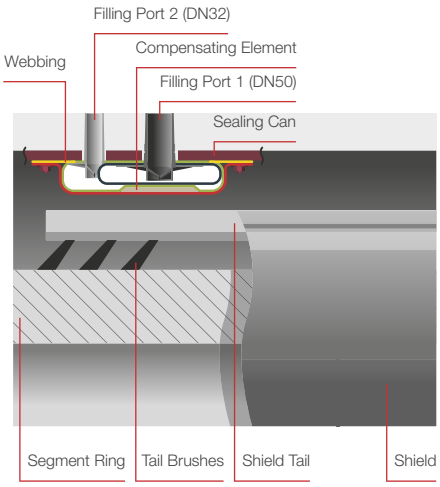
– Phase 1: the TBM cutterhead has passed by the sealing can



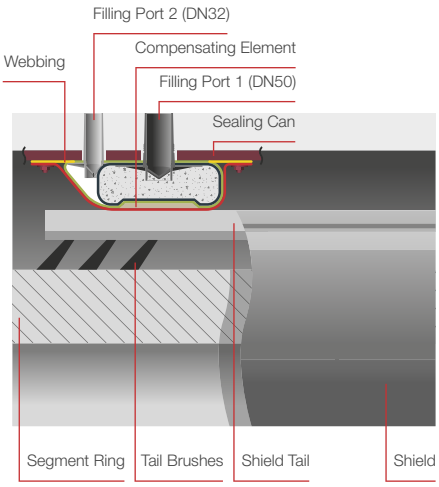
– Phase 2: the activated BULLFLEX® o-ring sealing allows start of the TBM under pressure
– The TBM drives through the BULLFLEX® o-ring sealing which seals the gap between sealing can and shield
– Conicities or eccentricities are balanced out by a compensating element

BULLFLEX® O-Ring Sealing
Filled BULLFLEX® O-Ring Sealing
Protective Cover

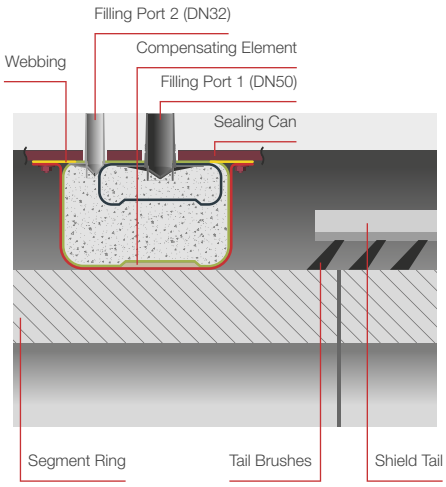
Hose-in-Hose O-Ring Sealing Can/Shield and Can/Segment



– A hose-in-hose system is a combination of a can/segment and a can/shield sealing
– Phase 1: the shield of the TBM is located in the area of the BULLFLEX® o-ring sealing

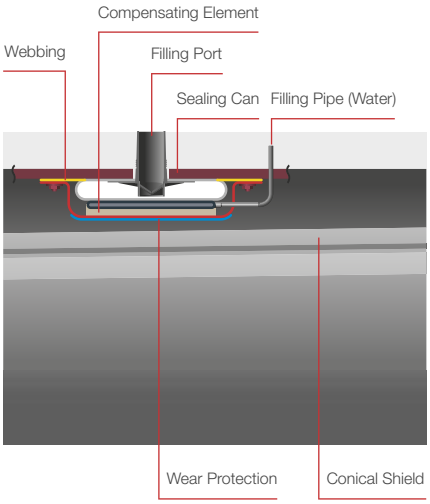


– Phase 2: the inner hose of the BULLFLEX® o-ring sealing seals the annulus between can and shield

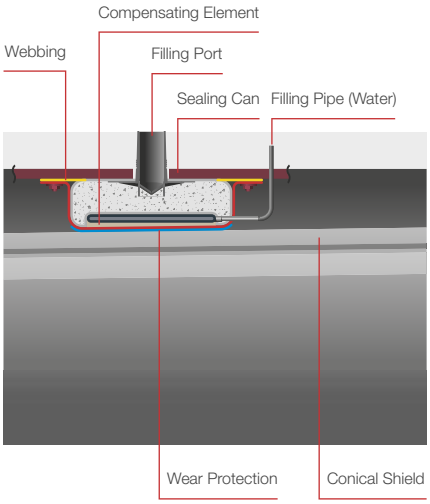


– Phase 3: the outer hose of the BULLFLEX® o-ring sealing seals the annulus between sealing can and segment

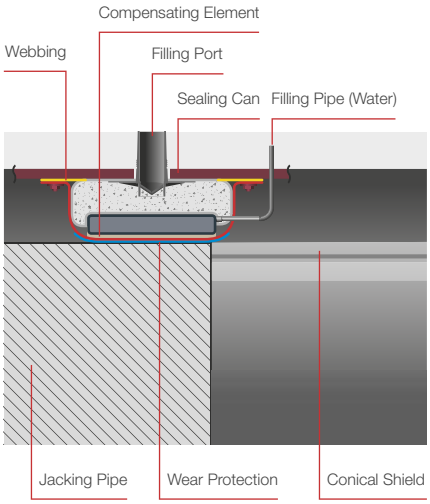
O-Ring Sealing Pipe Jacking



– Phase 1: the cutterhead of the micro TBM has passed the sealing can

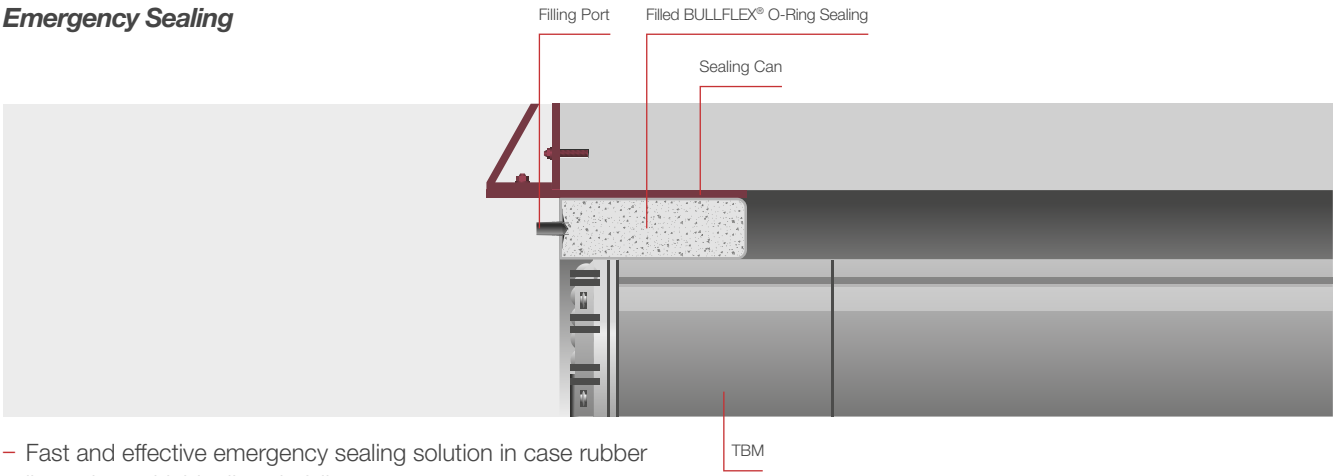


– Phase 2: the activated BULLFLEX® o-ring sealing allows the start of the micro TBM under pressure
– The micro TBM drives through the BULLFLEX® o-ring sealing which seals the gap between sealing can and shield



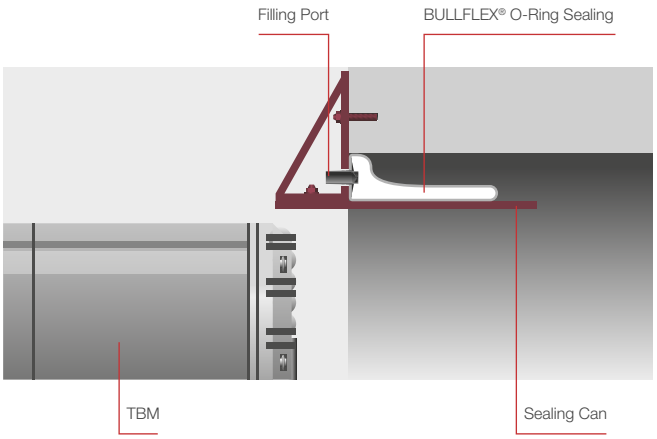
– Phase 3: conicities or eccentricities are balanced out by a compensating element
– An optional liquid-filled secondary sealing can be activated as additional measure

Emergency Sealing

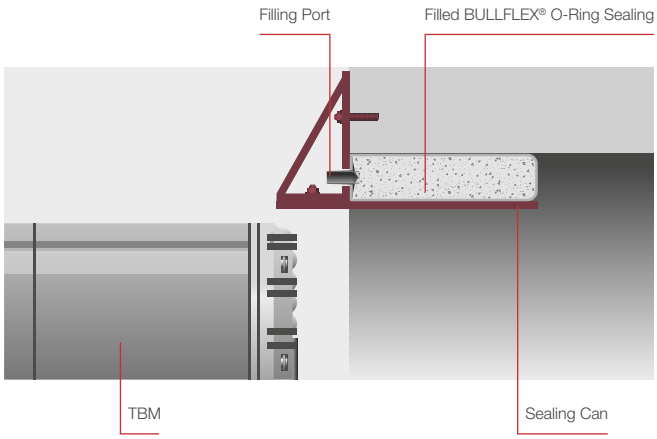


– Fast and effective emergency sealing solution in case rubber lip seals or shield tail seals fail

O-Ring Sealing Can/Ground

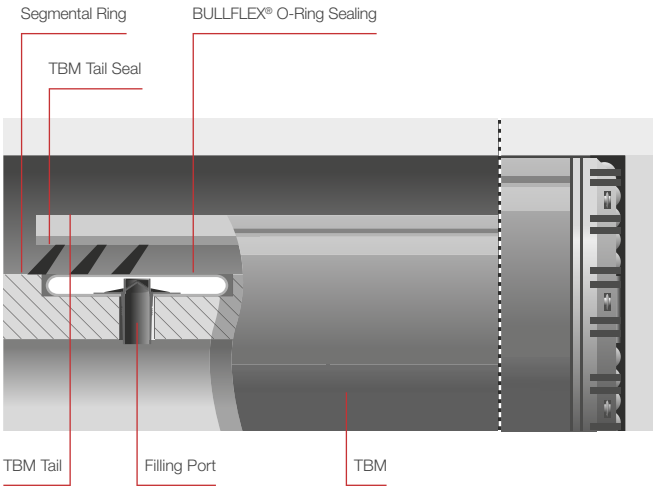


– Phase 1: integration of the BULLFLEX® o-ring sealing into a support ring

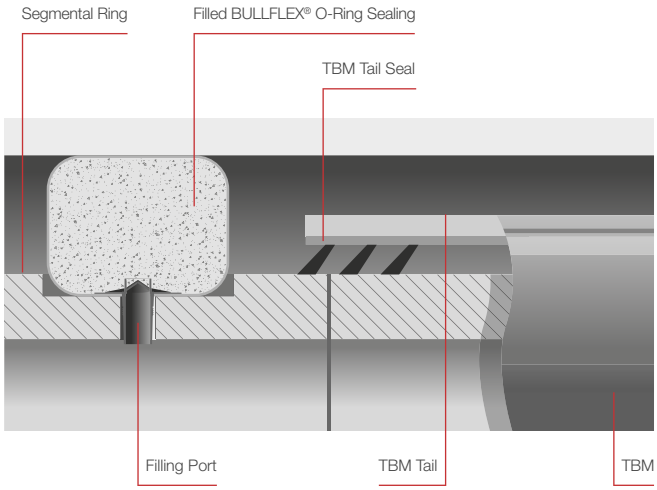


– Phase 2: activation of the BULLFLEX® o-ring sealing
– Simple and fast sealing solution

Segmental Sealing

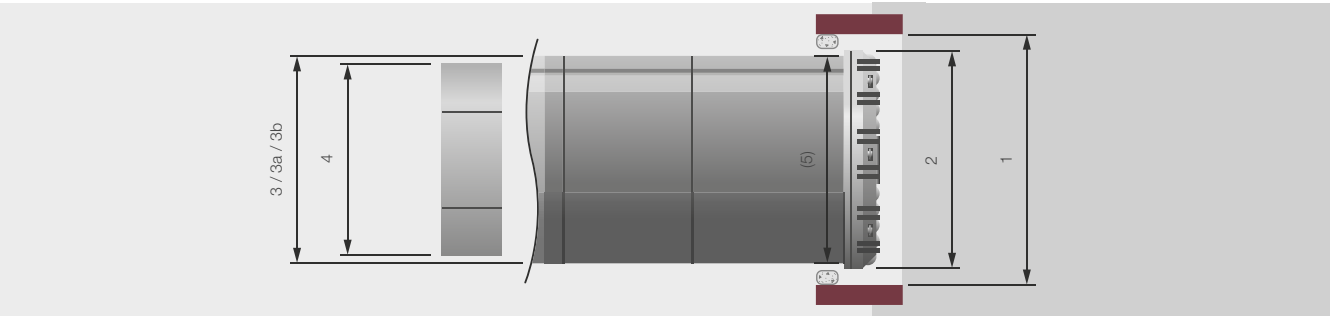


– BULLFLEX® segmental sealings are integrated into recesses in the outer side of each concrete segment of one complete ring
– Particularities such as grout ports or vacuum lifting points have to be considered



– Once the TBM tail seal has passed the segments where the BULLFLEX® segmental sealings are installed, activation is accomplished by simultaneous filling

Relevant Design Information

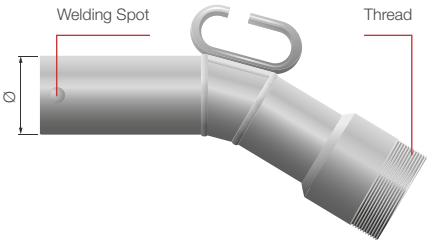


Parameter	Unit	No.
Inner diameter sealing can	[mm] / [in]	1
Outer diameter cutting wheel	[mm] / [in]	2
Outer diameter shield	[mm] / [in]	3
Only for tapered shield skin: max. outer shield diameter	[mm] / [in]	3a
Only for tapered shield skin: min. outer shield diameter	[mm] / [in]	3b
Outer diameter segment	[mm] / [in]	4
Tolerance of eccentricity (pipe jacking)	[mm] / [in]	(5)
Water (or backfilling) pressure	[bar] / [psi]	–

System Components

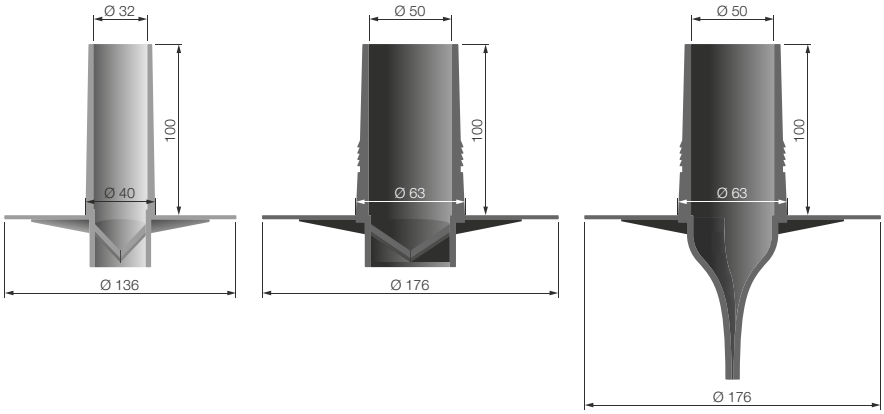
- BULLFLEX® groutable hoses
  - Patented endless round woven fabric made of polyamide 6,6
  - High resistance against tearing and no longitudinal seams
  - Anti-static, flame resistant, and self-extinguishing
  - Nominal outer diameter range: 230 [mm] (9,1 [in]) to 800 [mm] (31,5 [in])
  - Off-size diameters and special designs are available upon request
  - Default rated pressure 4 [bar] (58 [psi]), max. customized pressure up to 8 [bar] (116 [psi])
  - Retention of the grout mineral content while draining due to the special filter effect of the BULLFLEX® system
  - Air and water permeable
- BULLFLEX® filling ports
  - With check valve, inner diameter 32 [mm] (1¼ [in]) or 50 [mm] (2 [in])
- Flexible functional sealing inserts and protective inserts for the improvement of sealing capabilities
- Watertight inlets for up to 8 [bar] (116 [psi]) – emergency sealings and adjustment of existing sealings
- Protective covers and compensating elements
- Fixing devices
  - Webbings
  - Hook-and-loop tapes
  - Clip systems
- Filling material
  - See table for recommended injection material

Filling Nozzle DN 32 / DN 50



Filling Port	DN 32	DN 50
Ø [mm]	28	45
Thread ["]	1 ¼	2

Filling Ports



DN 32 *DN 50* *DN 50 for Coarse Aggregates*

Specifications

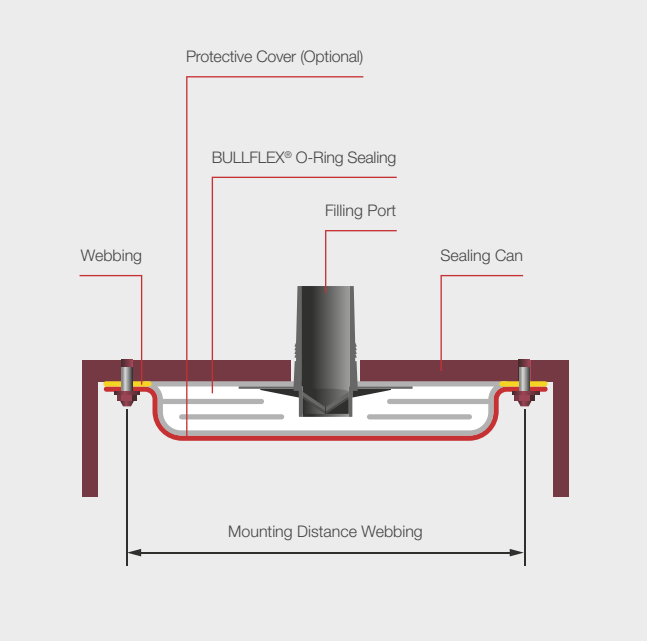
Characteristic [1]		Unit	Value	Remarks
Material		[–]	Polyamide 6,6	Nylon
Weight		[g/m²] / [oz/yd²]	Approx. 660 / 19,5	–
Fabric thickness		[mm] / [in]	Approx. 1 / 0,04	–
Minimum tensile strength	L [2] T [3]	[N] / [lbf]	12 000 / 2 698 24 000 / 5 395	100 [mm] / 3,94 [in] width According to ISO 10319
Corresponding maximum elongation	L [2] T [3]	[%]	20 20	According to ISO 10319
Elastic elongation	L [2] T [3]	[%]	15 15	According to ISO 10319
Minimum seam strength		[kN/m] / [lbf/ft]	155 / 113	–
Airflow through fabric at pressure [mbar] ([psi])	10 (0,15) 20 (0,30) 30 (0,45)	[L/min] / [gal/min]	6,5 / 1,7 13 / 3,4 19 / 5,0	At 100 [cm²] / 15,5 [in²]
Residual tensile strength		[%]	20 - 30	After 1 year and under light exposure in Florida

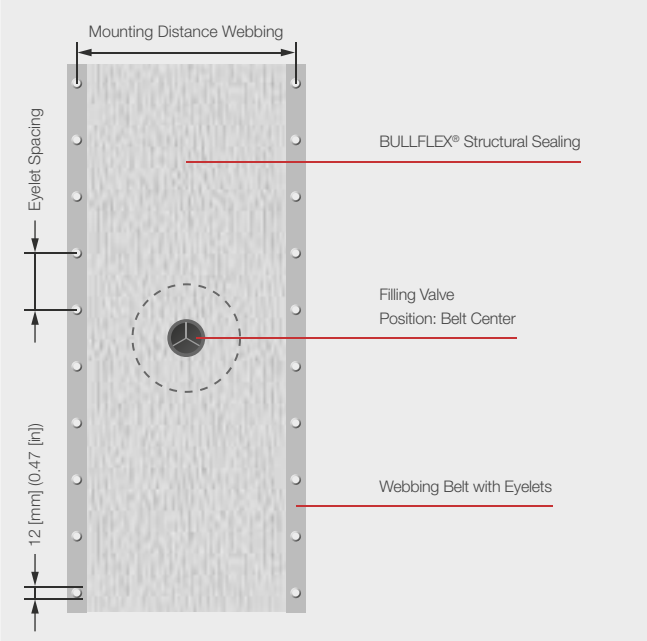
1) The indicated values are laboratory values and may deviate on-site.

2) Longitudinal.

3) Transversal.

Webbing

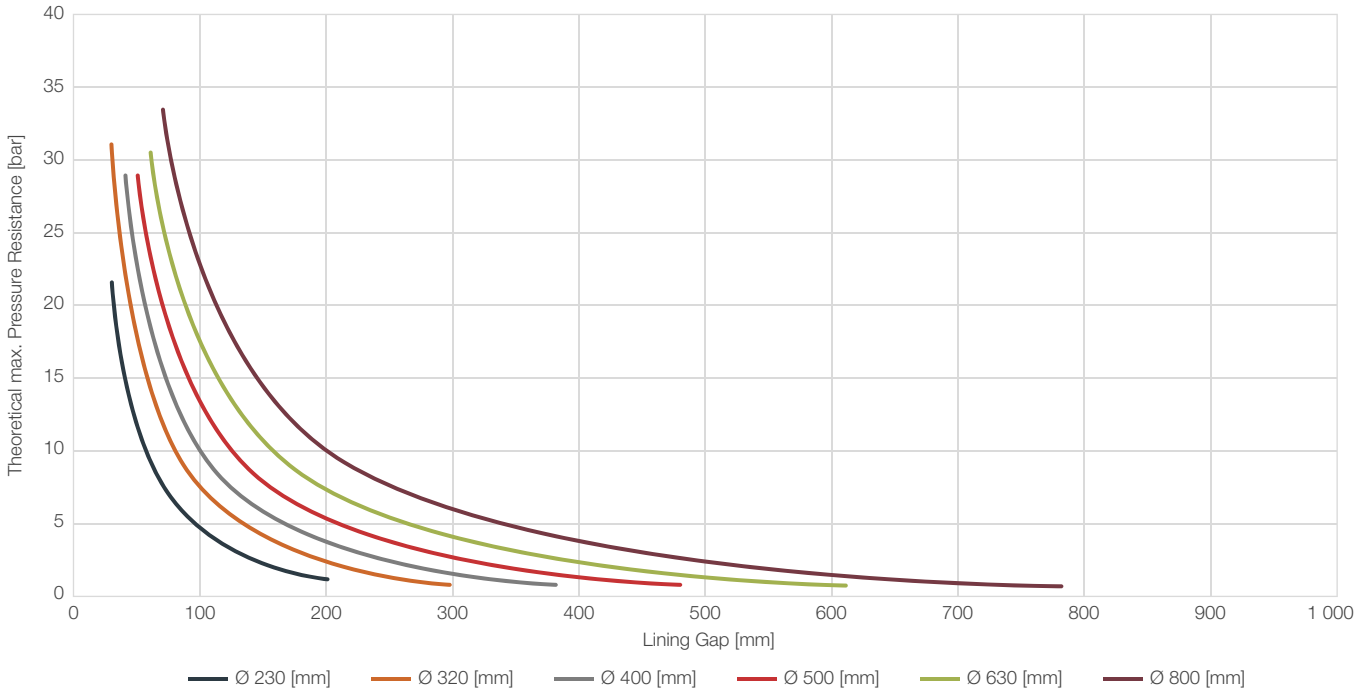




Eyelet Spacing	Mounting Distance		
	250	300	350
[–]	[mm]	[mm]	[mm]
100 [mm]	230 - 320	320 - 500	500 - 800
170 [mm]	230 - 320	320 - 500	500 - 800
11 [in]	230 - 320	320 - 500	500 - 800

Characteristics

Theoretical max. Pressure Resistance Depending on the Lining Gap and the BULLFLEX® Diameter



Installation Procedure

Mounting O-Ring Sealing Can/Shield or Can/Segment

1. Mounting of the BULLFLEX® o-ring sealing for marking of the welding spots

2. Welding of bolts/studs onto the sealing holder
   Note: BULLFLEX® hoses must be protected against sparks and molten steel

3. Fixation of the BULLFLEX® o-ring sealing in the upper area. Start of roll up with the center of the overlap at 6 o' clock position

4. Fixation of the BULLFLEX® o-ring sealing in the lower area

5. Fixation of filling pipes into the BULLFLEX® filling valves

6. To be able to ensure a proper grouting sequence, filling pipes should be marked with different colors

General Recommendations

- Ensure that injection hoses are laid out without kinks
- Avoid contact with any sharp edges in order to prevent the fabric from being damaged
- Screw pumps are high-pressure pumps, therefore only steel-reinforced hoses may be used for grout transport
- Before starting the machine, ensure that easily workable grout is being used
- The intake hose must not leak anywhere (especially not at connections), and the inner side of the hoses must be sufficiently lubricated
- Before removing the filling nozzle or the pump outlet flange, ensure that these components are de-pressurized by starting the main motor of the injection pump in reverse direction
- In order to prevent eye injuries, protective goggles must be worn, also when removing obstructions from the pump
- The person carrying out the task of pump operation must be at a safe distance from any material that may be discharged
- Accordingly, other people must be kept out of the immediate vicinity
- During inflation (cement injection), all default and recommended personal protective equipment must be used
- BULLFLEX® groutable hoses are resistant against tunnel water inflow; the fabric itself is only soluble in concentrated inorganic acids and phenol
- Further information is included in the BULLFLEX® material data sheet

Filling O-Ring Sealing Can/Shield or Can/Segment

- Double-check project-specific documentation and specifications: length, diameter, and number of filling ports
- BULLFLEX® o-ring sealings are inflated through a series of filling ports according to their labeling on the shaft
- Chronological order and amount of filling material which should be considered for each filling port as well as in total is provided by the project-specific documentation
- Only for the last filling port: increase of the filling pressure up to 4 [bar] (58 [psi]) or up to the pressure indicated in the project-specific documentation
- Once this rated pressure has been reached, wait for approx. 3 minutes. Then, continue to apply until a pressure of 4 [bar] (58 [psi]) has been reached again

Recommended Injection Material [1)]

Characteristic	Unit	Value	Remarks
Composition	[%]	25 - 50% portland cement 75 - 50% fly ash	Alternatively, stone powder or a mixture of fly ash and sand can be used instead of fly ash [2)]
Compressive strength after 1 day	[N/mm²] / [psi]	> 2 / > 290	EN 196 / ASTM C1019
Compressive strength after 28 days	[N/mm²] / [psi]	> 25 / > 3 630	EN 196 / ASTM C1019
Slump class	[–]	Medium-high	EN 12350-5 / ASTM C143
Max. grain size	[mm] / [in]	3,8 / 0,15	Default aggregate grading curve
W/C ratio	[1]	0,7 - 0,9	–
Setting time	[min]	30 - 120	–

1) Further references: ASTM C1107; ASTM C827; ASTM C143; EN 1045; EN 206-1.

2) Aggregates may not have constituents harmful to concrete.

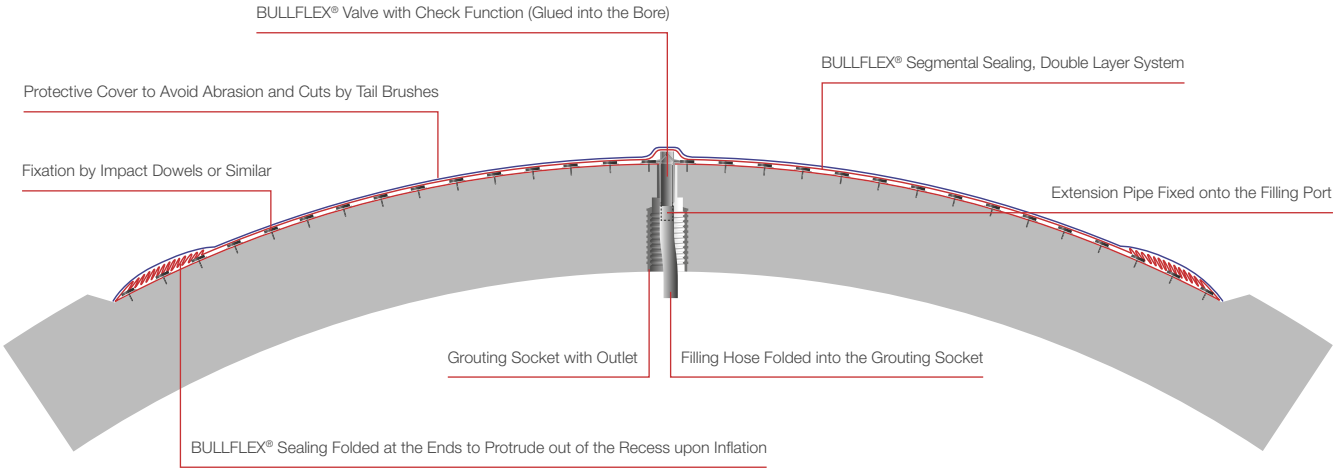
Main Factors Affecting the Workabiliy of the Injection Medium

- Water-cement ratio
- Amount and type of aggregate and cement
- Ambient temperature
- Chemical admixtures

Requirements Pumping and Mixing Equipment

- Application of either a separate mixing and pumping unit, or a combined mixing/pumping device
- Pumpable with standard worm pumps for flooring or injections works with a nominal power of 7,5 to 12 [kW] and a minimum flow rate of 20 [L/min] (5 [gal/min])
- Default filling rates should be in the range of approx. 80 - 180 [L/min] (21 - 48 [gal/min])

Segmental Sealing and Bedding



- BULLFLEX® segmental sealings
  - Reduction of water circulation
  - Prevention of backfilling washout
  - No floating of the segment column

- BULLFLEX® segmental bedding
  - Immediate contact between segments and ground
  - Avoidance of ovalization
  - No redistribution of pea gravel
  - Stabilization in the area of cross-cuts or extended sections, e.g. prevention of settlements or angular distortion

AT – GRP Injection System

Introduction

The AT – GRP Injection System is an AT-SYSTEM with glass fiber reinforced casing pipes (GRP), which is installed self-drilling. This system is mainly used when steel is not desired in the ground or where injection pipes are excavated by a TBM afterwards.

The injection pipes permit an insertion of any kind of ground influencing injection media into the ground. These injections may serve for ground improvement or waterproofing. The AT – GRP Injection System can thus be installed in jointed rock as well as in weak ground conditions.

Main Advantages

- Installation with standard drilling machines
- Drilling works can be executed by on-site personnel under the supervision of application engineers
- Time-saving installation due to simultaneous drilling and tubing (self-drilling)
- GRP pipe length may be adapted to the space available
- GRP injection pipes can be cut and mucked out by a TBM cutting wheel

System Description

The AT – GRP Injection System is installed piecewise by rotary-percussive drilling with conventional drill booms. The cooling of the drill bit and flushing of the cuttings take place inside the GRP tube.

After installation, different kind of media can immediately be injected into the ground in order to improve ground properties or to accomplish watertight conditions.

System Components

AT – Starter Unit with Drill Bit

AT – GRP Extension Tubes

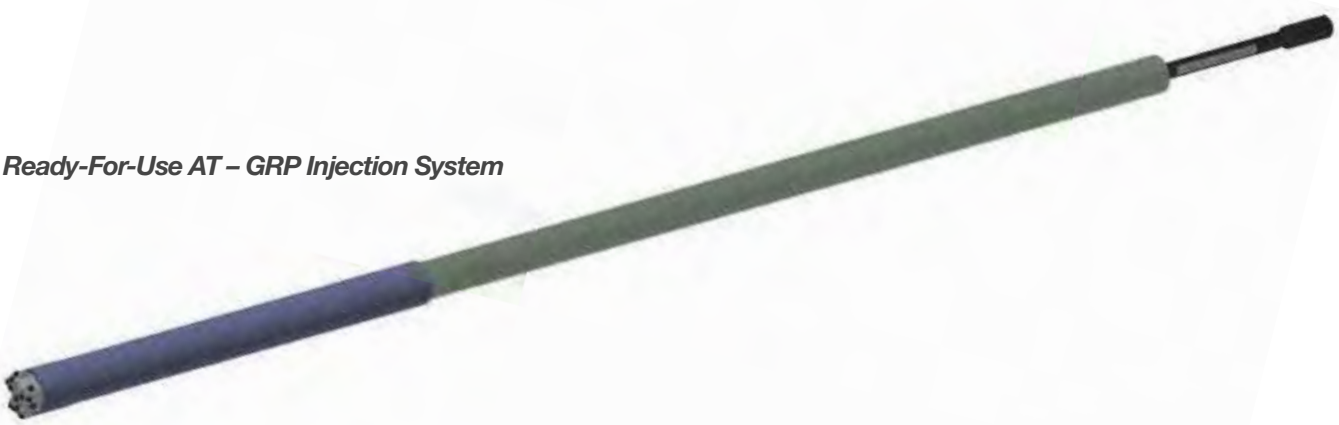
Aluminum Coupling

Drill Bit Adapter

Coupling Adapter
and Drill Rods

Grouting Plug with Ball Valve

Ready-For-Use AT – GRP Injection System



Specifications

- AT – 76 GRP extension tubes: outer diameter 76 [mm] (3 [in]), wall thickness 8 [mm] (5/16 [in])
- Standard tube lengths: 1,0 / 2,0 / 3,0 [m] (3,3 / 6,6 / 9,8 [ft])

Technical Features

- The length of the AT – GRP Injection tubes can easily be adapted due to the piecewise installation
- Simple extension of GRP tubes even in confined working space
- High drilling accuracy during installation
- TBM drilling equipment may be used for installation
- Optional application in combination with steel extension pipes

Installation Procedure

1. The starter unit with single-use drill bit is connected to the first GRP extension tube. This part is then prepared on the drill boom together with the drill bit adapter and the drill rods.
2. Drilling of the first GRP extension tube.
3. The next GRP extension tube and the drill rod are connected with the previously installed part and are drilled subsequently.
4. Repeat the last step until the designed length including the GRP end tube has been installed.

Accessories

- Injection flow-pressure meter
- Sleeve pipe packer
- Deep injection packer
- Grout mixing pump
- DSI Inject Systems
- Fishing tab
- Chain pipe wrench
- Drill rod wrench
- Centralizer
- Rock drilling equipment: shank adapter, coupling, and coupling adapter

AT – Starter Unit with Sealing Function

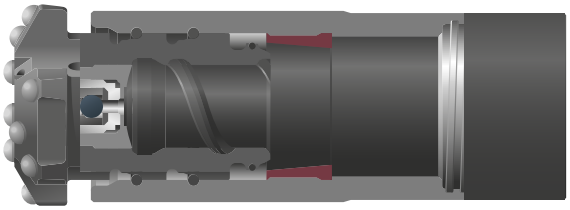
DSI Underground has developed a special starter unit with sealing function which enables the application of an injection or pipe umbrella in ground conditions with a high ground water inflow under pressure.

Sealing of the drill string is accomplished by:

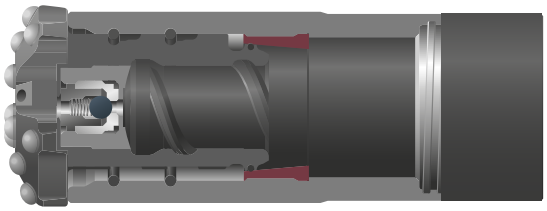
- Use of a blow-out preventer (BOP) which seals the annulus between borehole wall and casing tube
- Dual sealing of the inner drill string by a check ball valve and a radial o-ring sealing

Starter Unit: AT – 89, AT – 114, or AT – 139

Drilling Position (open)



Extension and Sealing Position (closed)



System Components – Combination Steel and GRP

AT – Starter Unit with Drill Bit

AT – Steel Extension Tubes

AT – Steel Extension Tube with GRP Connection Thread

AT – GRP Extension Tubes

Aluminum Coupling

Drill Bit Adapter

Coupling Adapter and Drill Rods

Grouting Plug with Ball Valve

Product Index

DSI UNDERGROUND
A SANDVIK COMPANY

Please note:
This brochure serves basic information purposes only. Technical data and information provided herein shall be considered non-binding and may be subject to change without notice. We do not assume any liability for losses or damages attributed to the use of this technical data and any improper use of our products. Should you require further information on particular products, please do not hesitate to contact us.

ALWAG SYSTEMS

DSI Underground Australia Pty Ltd
Newcastle Head Office & Manufacturing Facility
25 Pacific Highway
NSW 2290 Bennetts Green
Australia

Phone +61 2 49489099
E-mail sales@dsiunderground.com.au

www.dsiunderground.com.au

04394-1/11.21-5000 He Ho