DSI Hollow Bar System

Civil engineering edition

SANDVIK

Content

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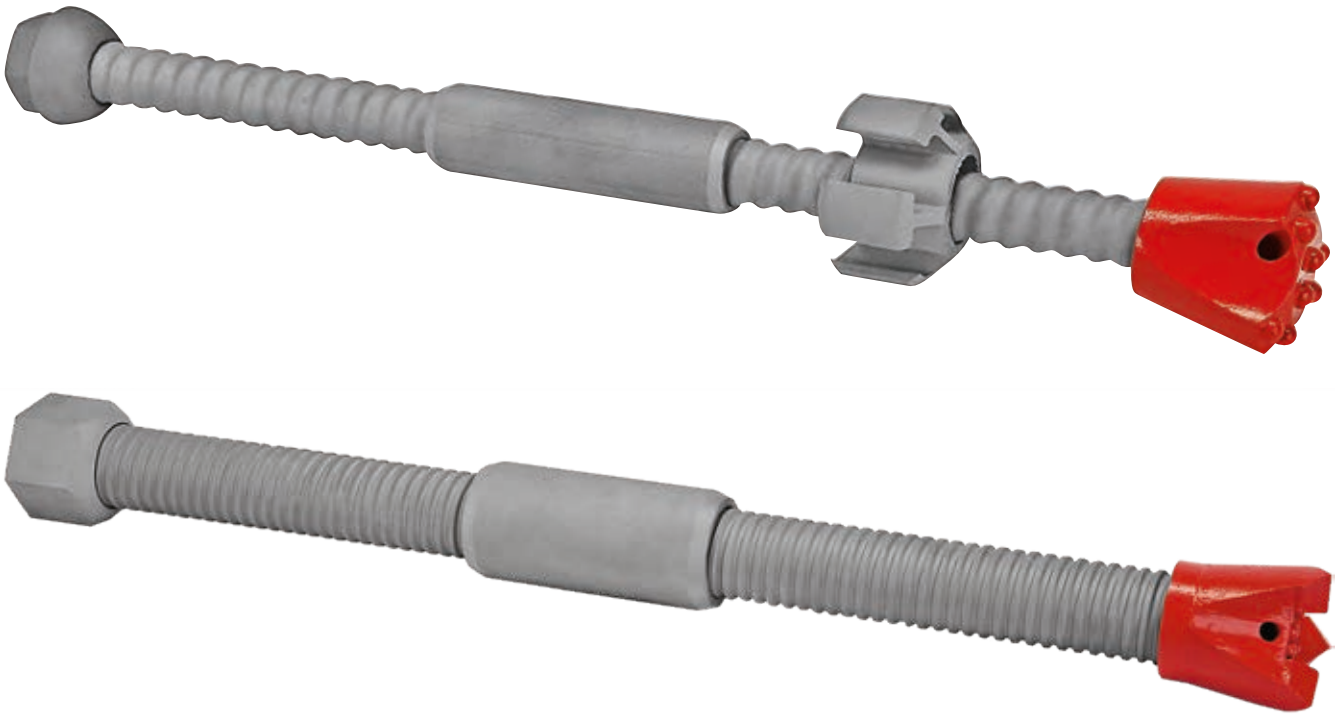
Introduction

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, piling, 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.
Sandvik Ground Support has long-term experience in the design, development, manufacturing, testing, and distribution of the DSI Hollow Bar System.



Manufacturing and competence center

MADE IN EUROPE

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

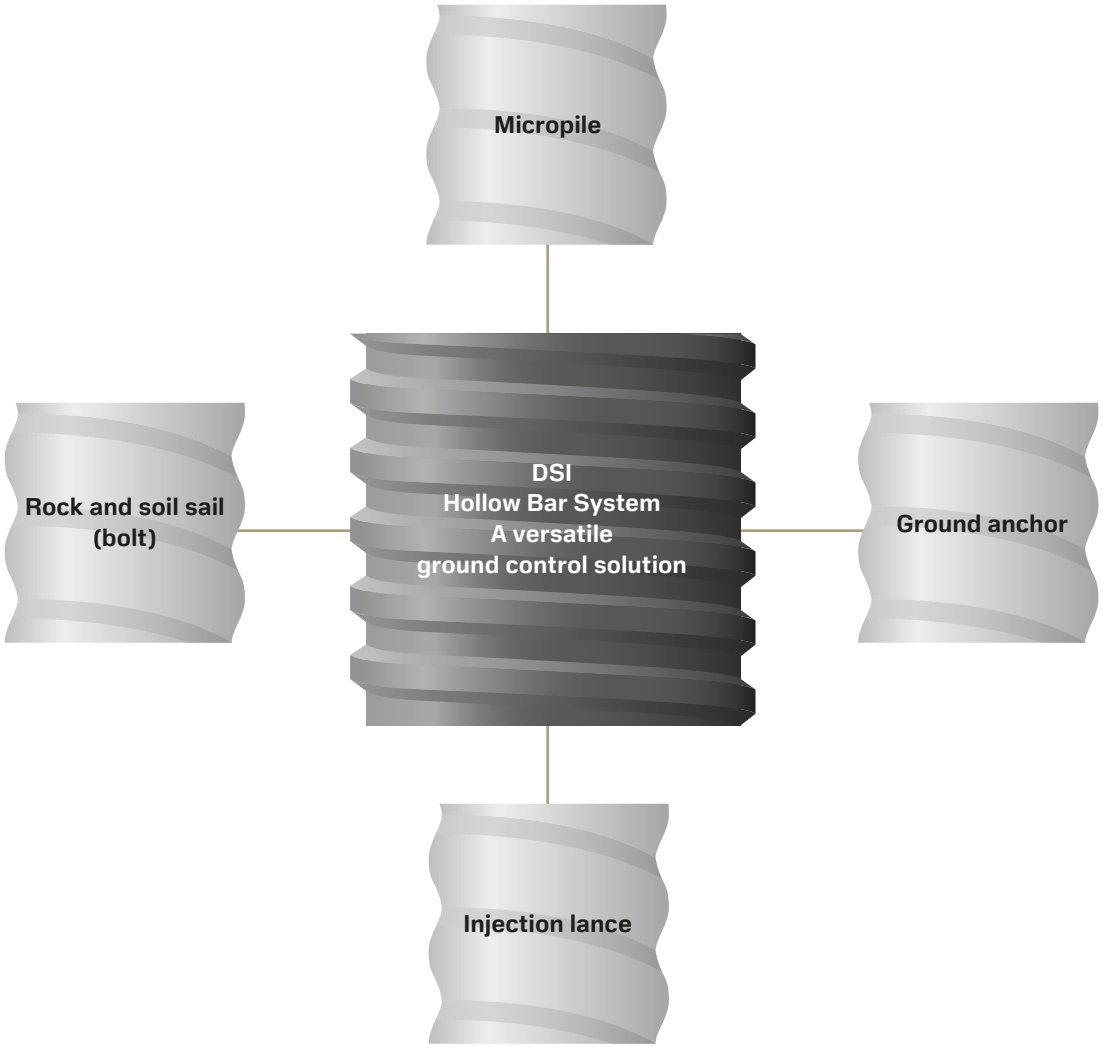
Figures

— 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
  - Sandvik Ground Support production system based on TPS and lean management

System solution

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 simultaneously during drilling with a rotary injection adapter or after the drilling operation (post injection)
- Threaded profile allows an ideal bond between the hollow bar and the grouting medium



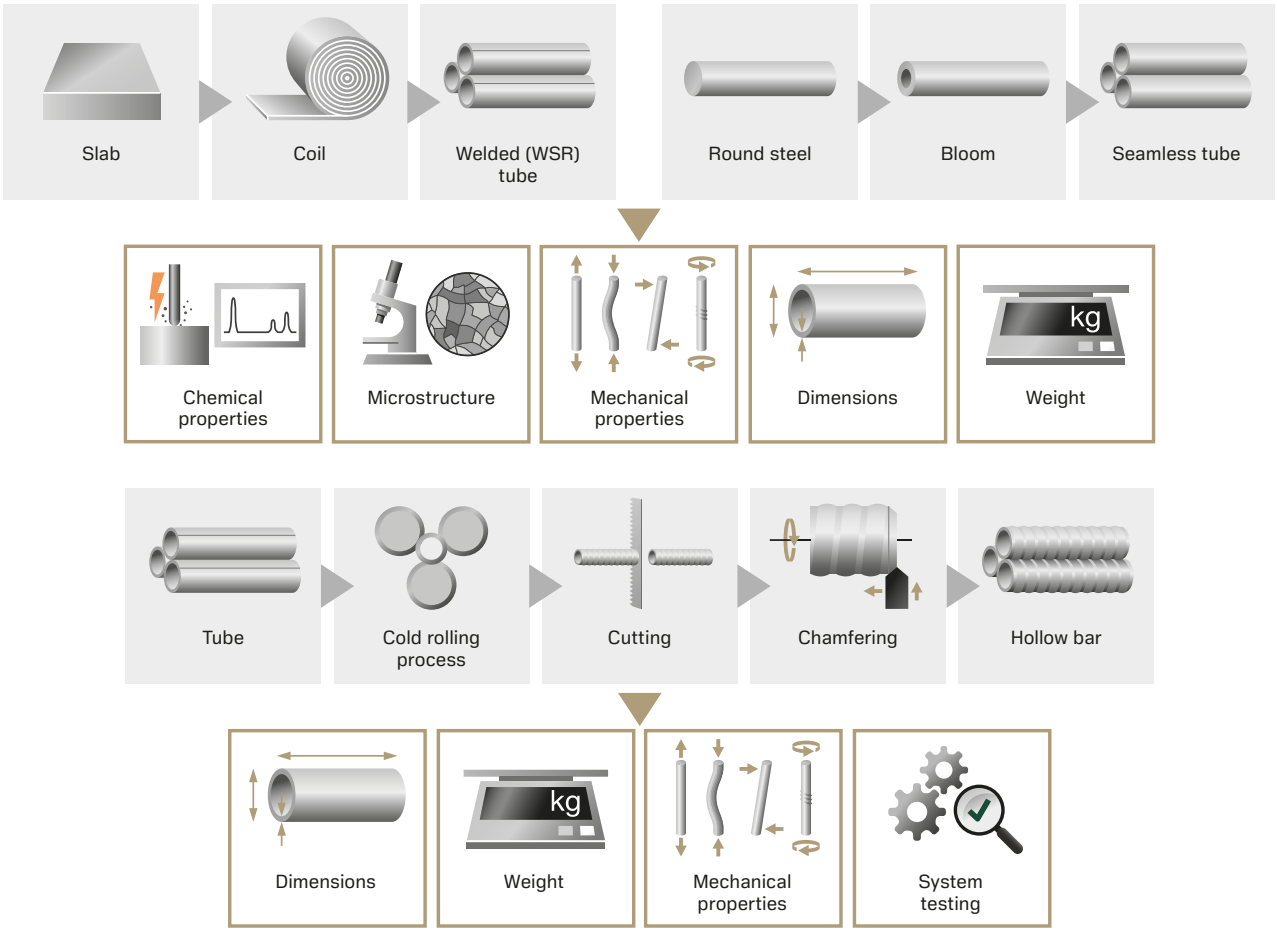
Main advantages

- 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

Quality assurance

Sandvik Ground Support's comprehensive services include the conception, design, planning, and installation of its systems, as well as quality management and on-site supervision.
To satisfy your requirements and needs, Sandvik Ground Support has implemented a quality assurance process for the DSI Hollow Bar System in accordance with the principles of total quality management. Quality means safety and reliability for our customers. Our aim is to provide product quality and safety throughout the entire manufacturing and distribution process.

In-process quality control



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

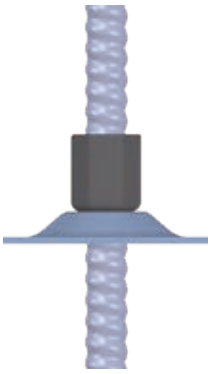
Design examples

Anchorage and foundation constructions

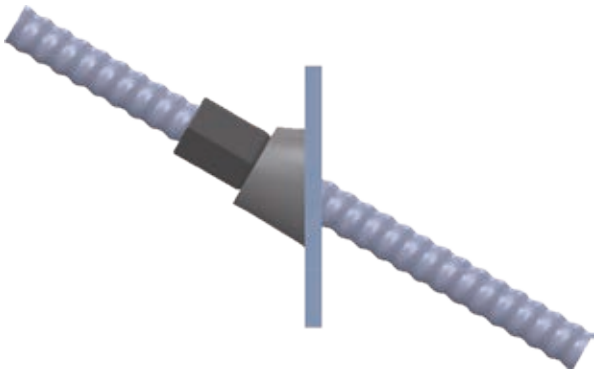
— **Nut**
- Hex or domed version
- Weldable square nut
- Different designs and dimensions available

— **Plate**
- Flat or domed
- Plate design adjusted to system demands
- Various solutions for angle compensations and special plate designs available

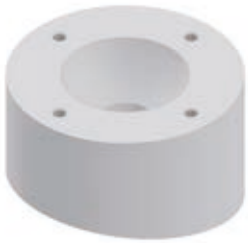
Design examples



Nail head with domed plate

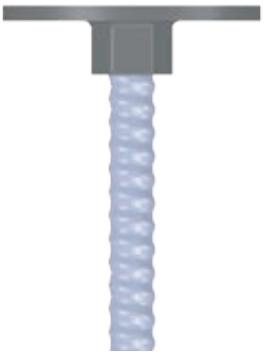


Anchor head with angle compensation



Hybrid plate

Micropile head



Reverse anchor head

System accessories

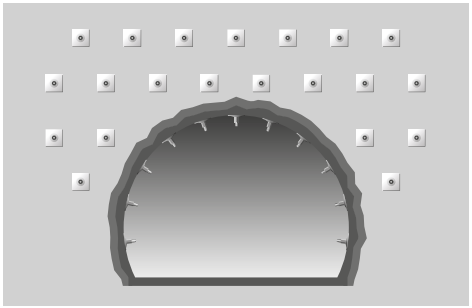
— **Structural elements**
- S-D expansion bolt
- Expansion shell
- Yielding anchor head
- Lock nut
- Eye nut and loop nut
- Bail nut
- Reverse anchor head
- Lock coupling
- Angle compensation disk
- Sleeve for free length
- Protective cap

— **Drilling, grouting, and monitoring**
- Bayonet connector
- Injection adapter
- Rotary injection adapter
- Grout mixing pump
- DSI Inject Systems
- Sealing coupling
- Post-injection coupling
- Drill bit adapter
- Rock drilling equipment
- Centralizer
- Injection flow-pressure meter
- Pull testing equipment
- Drill rod wrench
- Tensioning tool

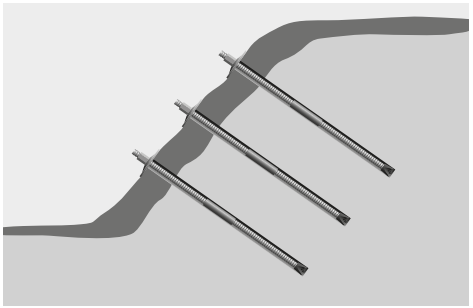
Rock and soil nail

Fields of application

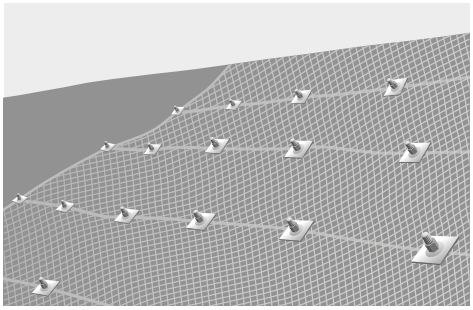
Portal stabilization



Slope stabilization

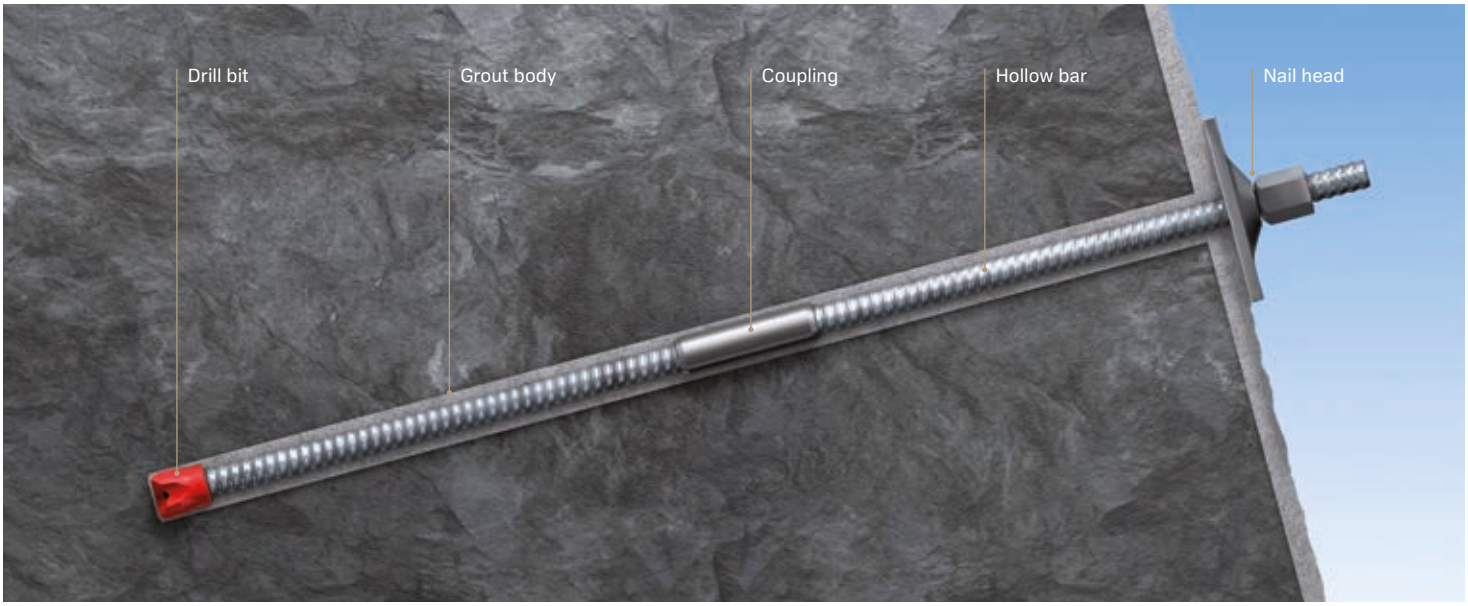


Rock fall protection



Basic concept

Soil nailing is a construction technique generally used for the stabilization of naturally unstable slopes or securing of over-steepened existing slopes, as well as the stabilization of retaining walls or embankments. For underground applications, soil nails are also referred to as rock nails or bolts.
The basic concept of a soil or rock nail is based on the installation of longitudinal reinforcement elements into the ground. Hence, this load-bearing system significantly differs from ground anchors (actively tensioned) and tensile piles, as the nail is installed un-tensioned (passive system). Consequently, nails increase the load-bearing capacity of the entire structure and act as a group of elements, withstanding tensile and shear forces acting on the nails. The center-to-center distance of nails must be chosen so that they are able to act as a complete nailing system. Prior to nail installation, the excavation face is generally supported by shotcrete, precast concrete elements, mesh, or geotextiles.
The design of a nail head construction depends on the application and the intended lifetime of the structure.
Conventional nail systems consisting of solid threaded bars are installed into pre-drilled holes and subsequently grouted.
Hollow bar rock and soil nails are installed self-drilling, and are either grouted simultaneously during drilling or afterwards.



Characteristics

— **Type and place of manufacture**
- At the location of its final function

— **Installation method**
- Pre-drilled and grouted (see section “ground anchor”)
- Self-drilling: borehole created by the installation process (drilling and flushing)

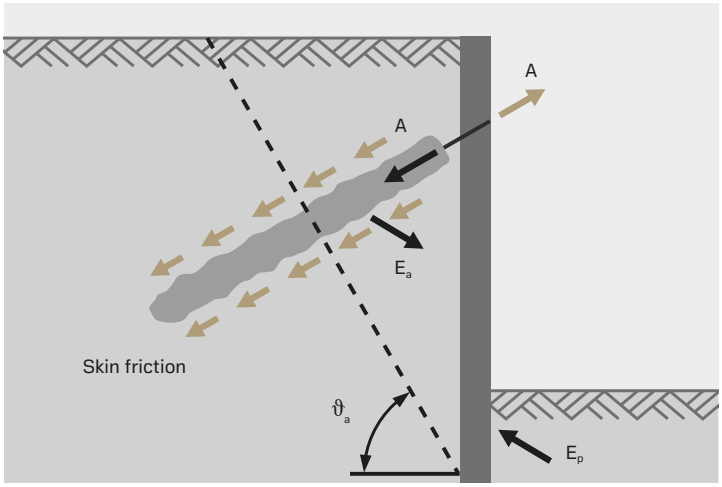
— **Load transfer mode**
- Frictional transfer between tension member, mortar (grout), and ground

— **Recommended corrosion protection methods**
- Sacrificial
- Double (DCP)

Approvals

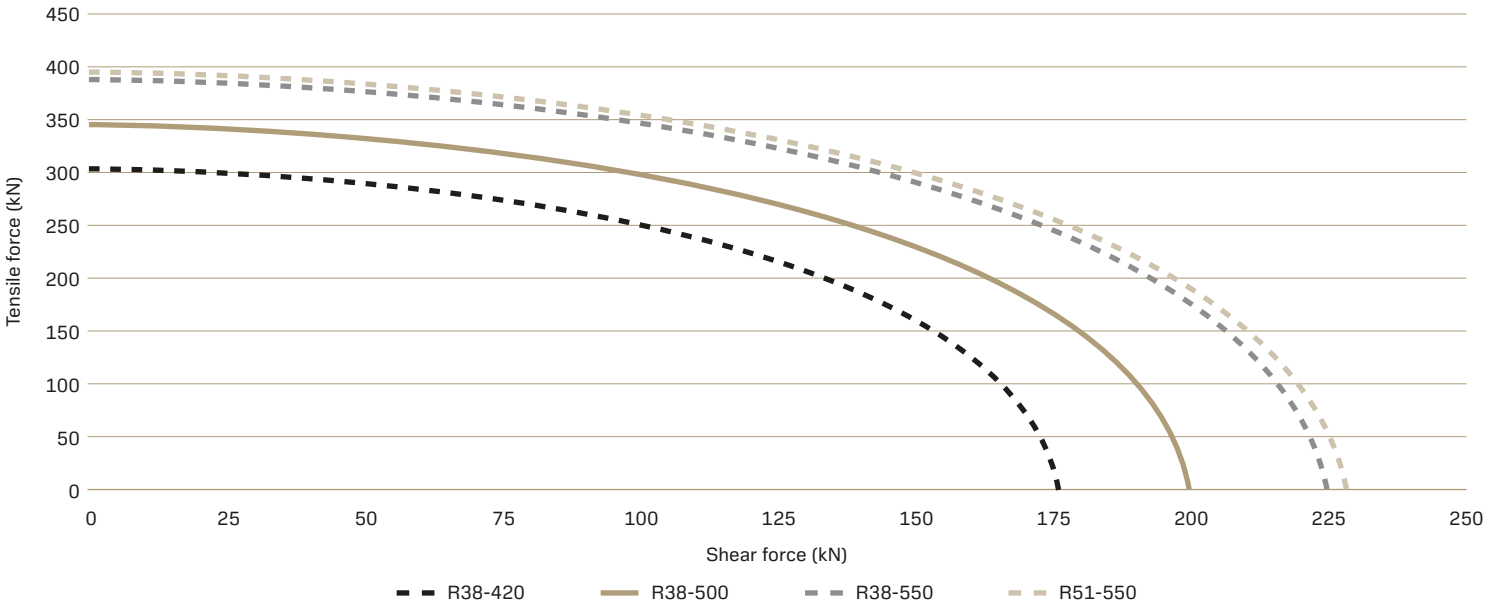
— European Technical Assessment (ETA)
— National technical approval in Austria (BMK)
— National technical approval in Slovenia (STS)
— German approval for underground application
— National technical approval in Poland (IBDiM)
— Project-specific approvals

Nailing



A = Axial force
ϑ_a = Friction angle
E_a = Active earth pressure
E_p = Passive earth pressure

Relationship of tensile and shear force



Design value tensile stress $\sigma_{R,d} = \frac{f_{y,k}}{1{,}15}$

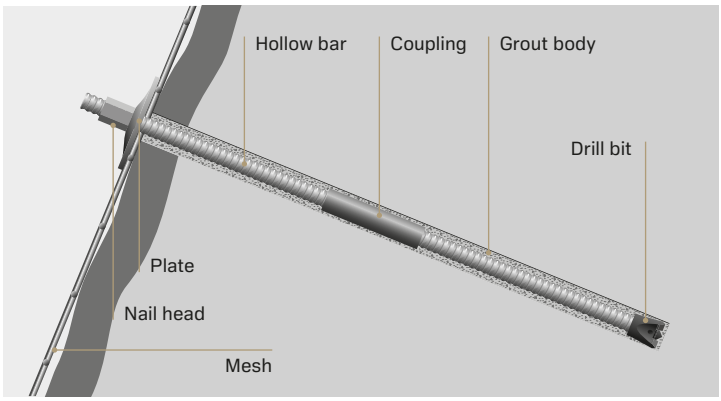
Design value shear stress $\tau_{R,d} = \frac{f_{y,k}}{\sqrt{3} \cdot 1{,}15}$

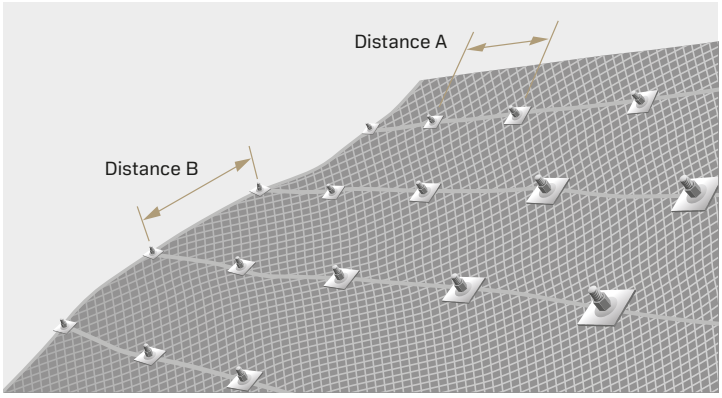
Ultimate shear load (design) $Q_v = \sqrt{(\sigma^2_{R,d} + 3 \cdot \tau^2_{R,d})}$

Head constructions

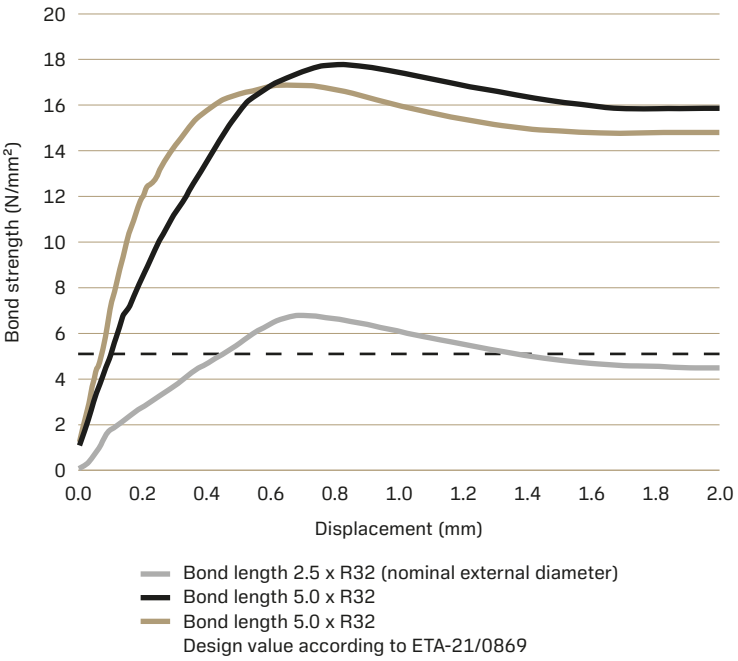
— Temporary head constructions
  - Service life ≤ 2 years
  - Plastic protective caps
— Permanent head constructions
  - Service life > 2 years
  - Protective caps made of or blank, hot-dip galvanized, or stainless steel
  - Alternative: GFRP caps
— Angle compensation constructions
  - Flat plate: up to 15°
  - Domed plate: up to 20°
  - Angle compensation disks: up to 55°
— Different types of utility nuts
  - Connection of environmental or rock fall protection mesh
— SMART DSI Hollow Bar System: customized monitoring system solutions

Rockfall protection





Bonding characteristics R32-400

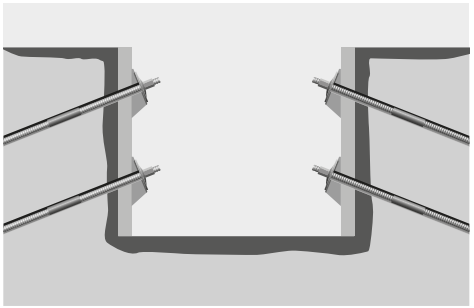


Applications

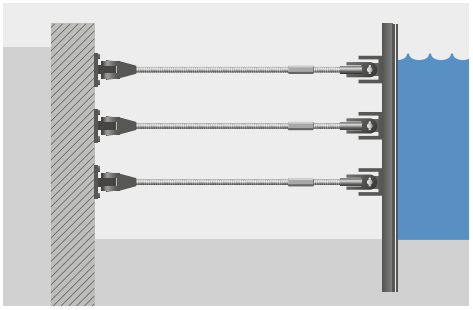
Ground anchor

Fields of application

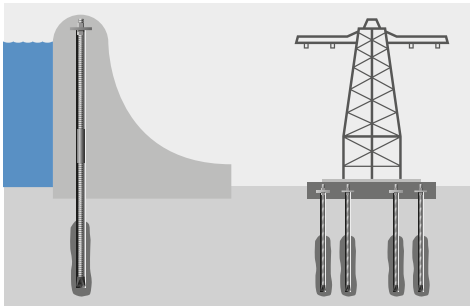
Tie back anchorage



Tie rods



Permanent tiedown



Basic concept

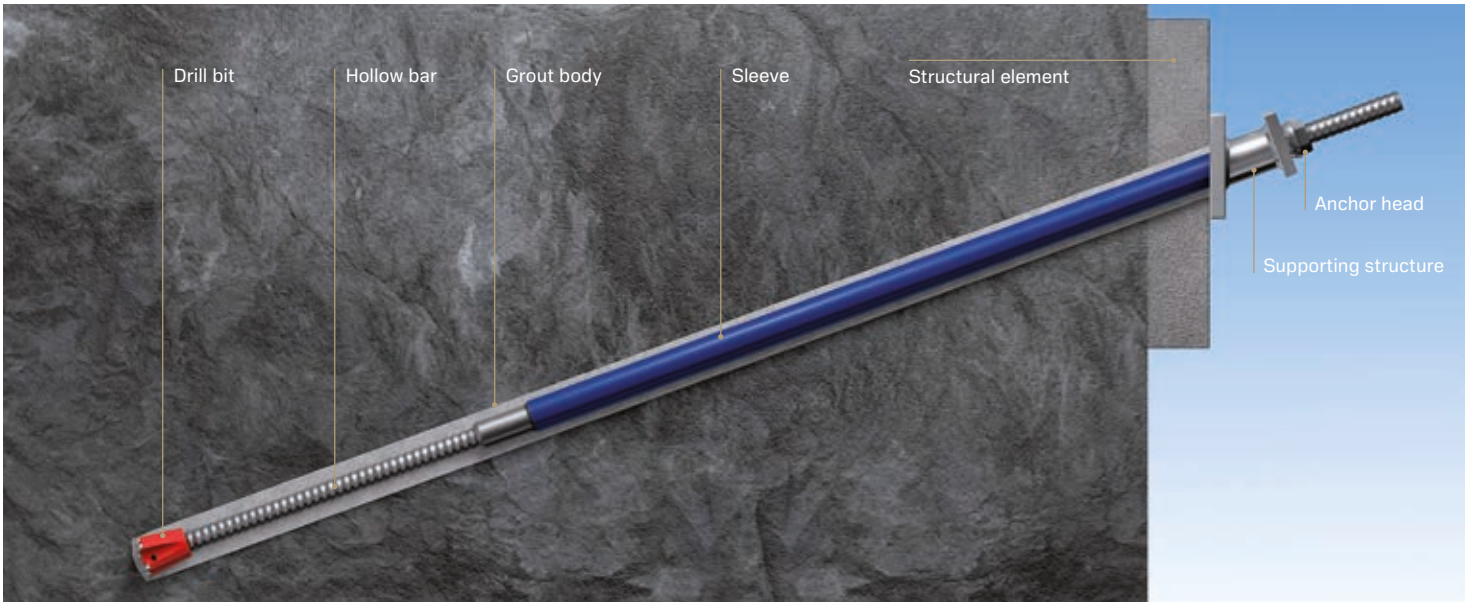
In civil engineering, ground anchors are elements which are actively tensioned to support structures. Due to the active tensioning of the system, anticipated deformations are minimized or entirely eliminated. Fields of applications are either temporary – such as excavation pits and retaining walls – or permanent, e.g. tie backs or permanent tiedown of masts.
By definition, ground anchors consist of the following three system components:

— **Bond length**
The anchor is set in the borehole using cement grout (mortar), and is able to transfer the forces to the load-bearing soil via bond and skin friction.

— **Unbonded (or free) length**
The tendon is uncoupled from the borehole wall using a sheathing (sleeve) which is sealed towards the coupling or hollow bar; the unbonded portion can freely be extended and tension can be applied to the anchor system.

— **Anchor head**
Transfers the anchor force to the substructure (e.g. precast concrete elements) that needs to be anchored.

Strand or solid bar ground anchor systems are installed into cased, pre-drilled holes and subsequently grouted. Hollow bar ground anchors are installed self-drilling with a pre-mounted sleeve attached to the drill string during installation.



Characteristics

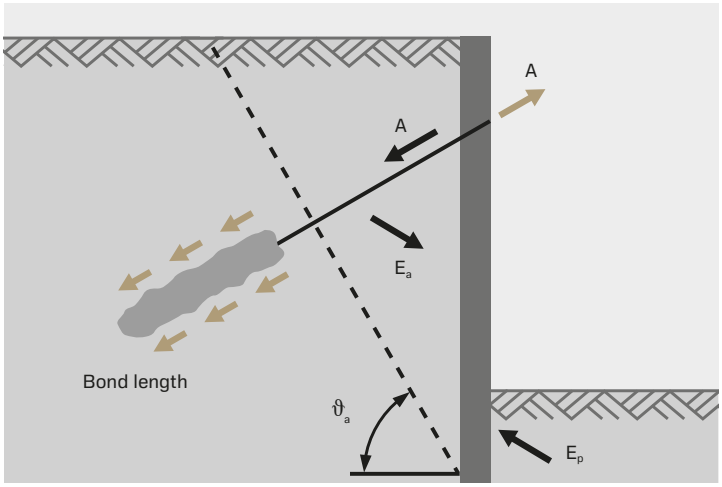
— **Type and place of manufacture**
- At the location of its final function or at the factory

— **Installation method**
- Pre-drilled and grouted
- Self-drilling: borehole created by the installation process (drilling and flushing)

— **Load transfer mode**
- Frictional transfer between tension member, mortar (grout), and ground

— **Recommended corrosion protection methods**
- Sacrifical
- Double (DCP)

Anchorage



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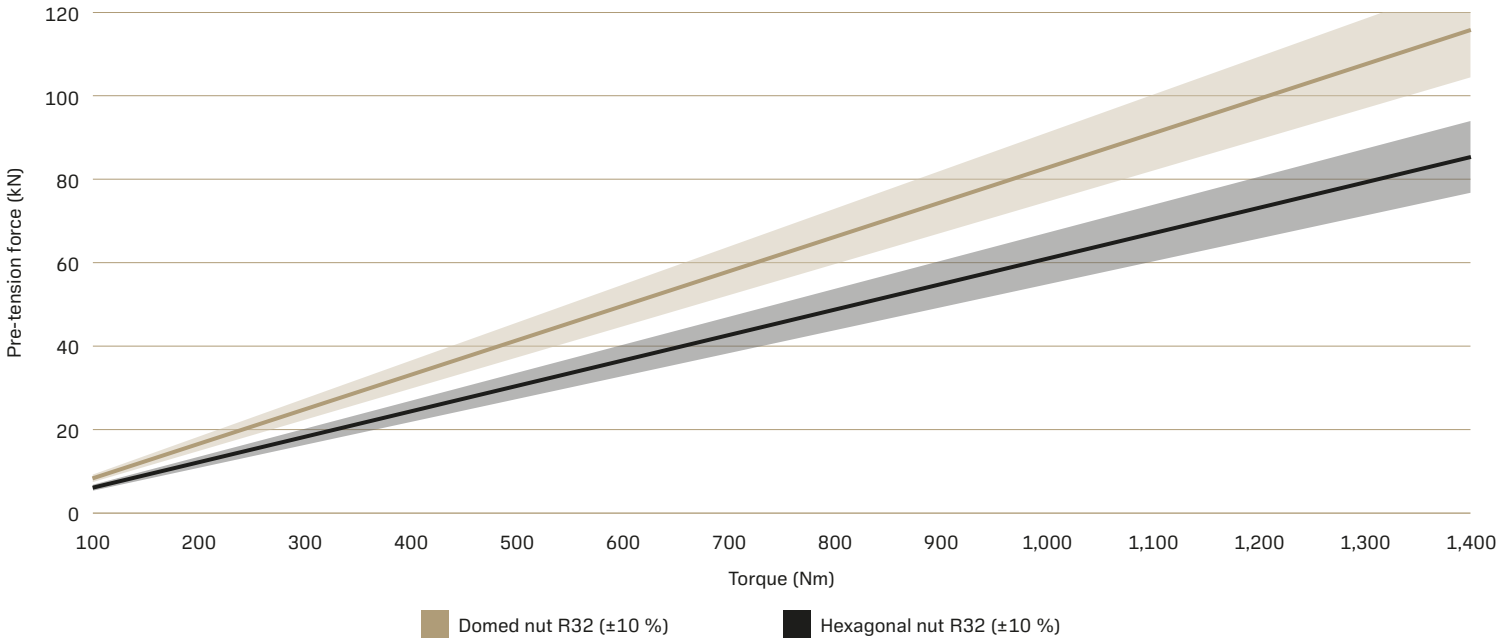
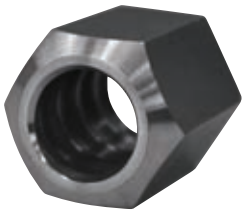
ϑ_a = Friction angle
E_a = Active earth pressure
E_p = Passive earth pressure

Torque-tension diagram DSI Hollow Bar type R32-280



Domed nut R32



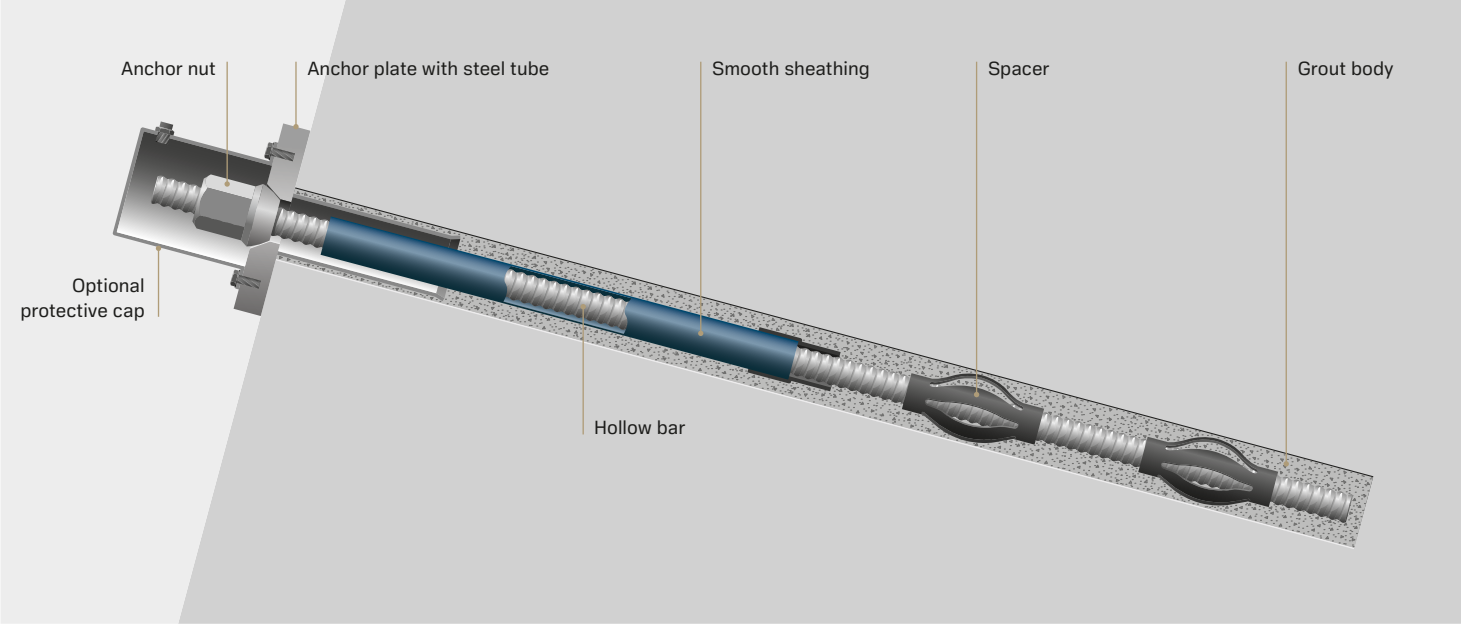
Hexagonal nut R32

Pre-drilled ground anchor system

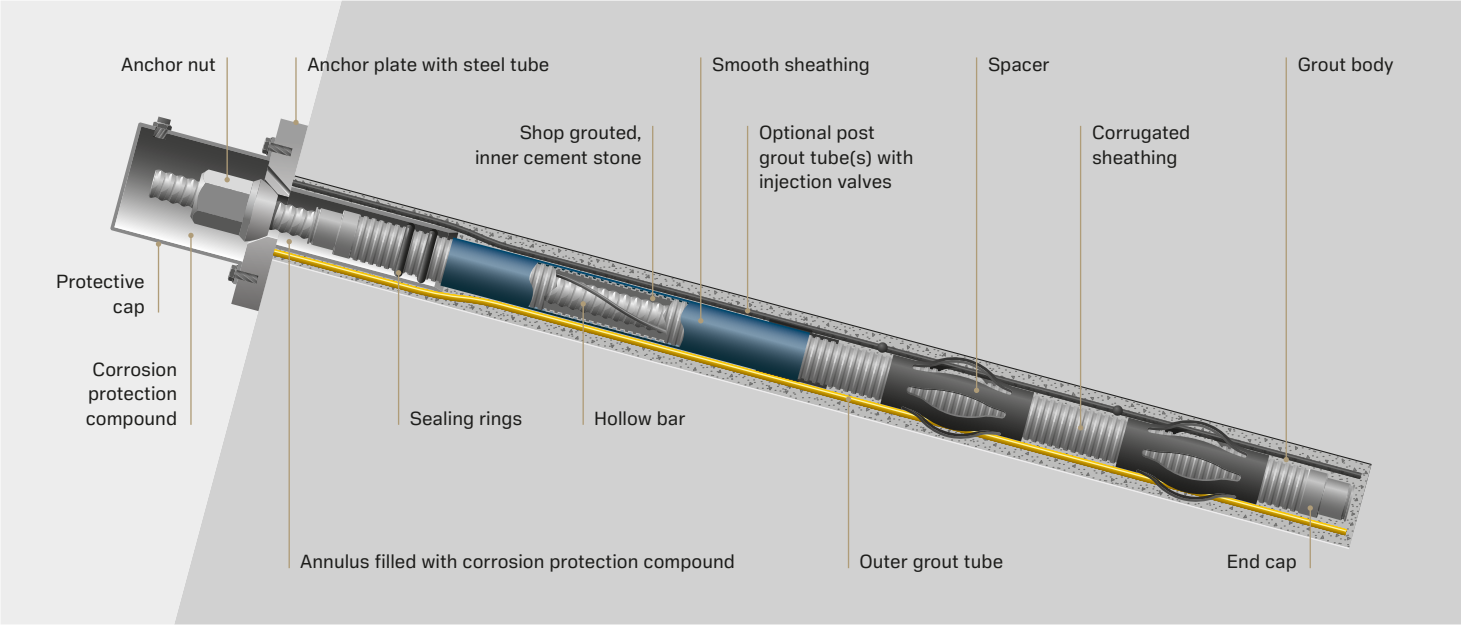
In addition to the self-drilling installation principle of the DSI Hollow Bar System, installation of an assembled hollow bar (without sacrificial drill bit) can also be executed intro pre-drilled boreholes. Here, installation requires stable borehole conditions as well as solid ground capable of developing an anchor body at the toe of the borehole.

The hollow bar is not only used as load-carrying member of the anchor, but it also furthermore serves as injection line making the grouting process easier compared to the use of separate attached grout hoses. This type of ground anchor can also be used for high-pressure or post-injection applications.
Both temporary and permanent pre-drilled ground anchor systems are available, depending on the intended lifetime.

Temporary

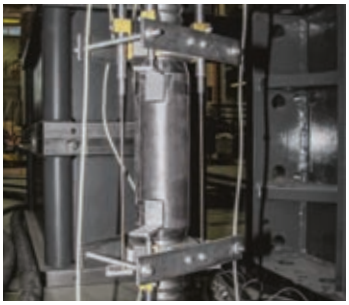


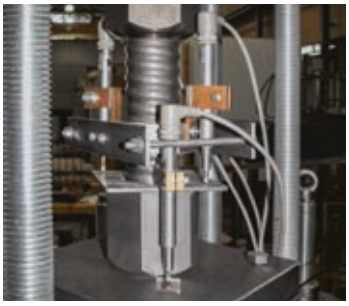
Permanent

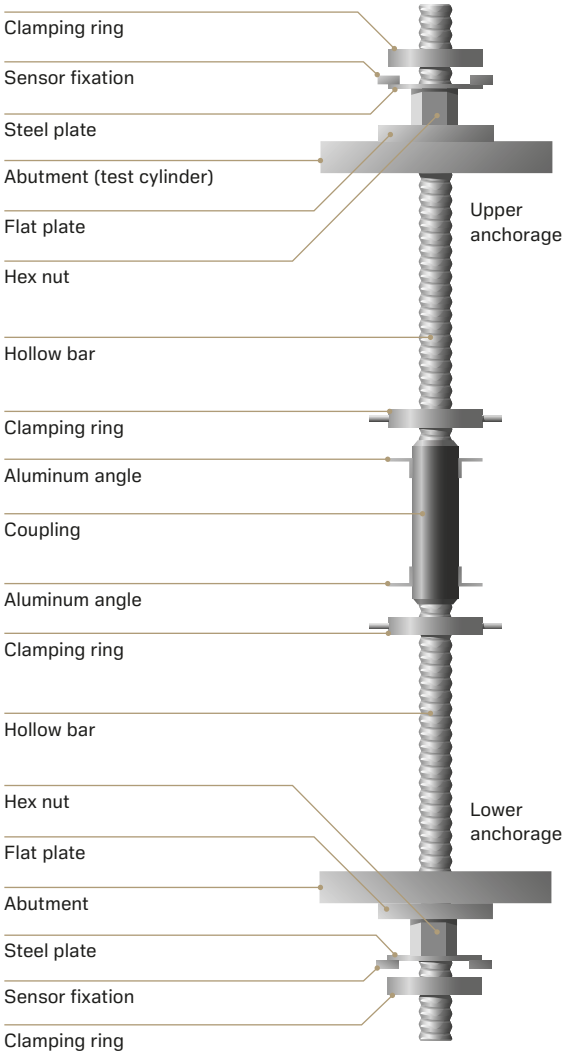


Fatigue testing

Types R32-400, R38-550, and R51-800
— Hollow bar tendons
— Couplings and anchorage (plate and nut)
— See ETA-21/0869







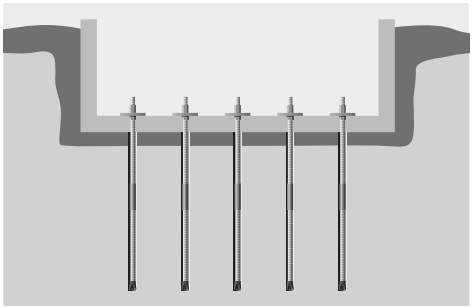
Source: Laboratory for Structural Engineering, Graz University of Technology (test report No. F-10-41-2012)

Applications

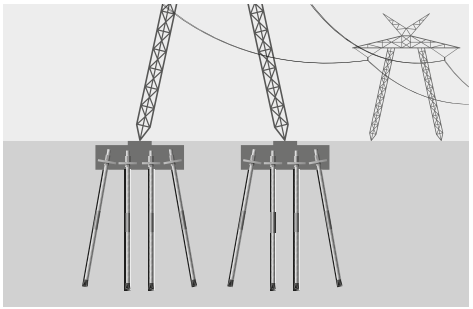
Micropile

Fields of application

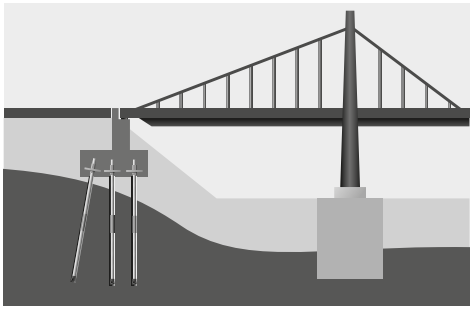
Uplift control



Pile foundation



Abutments



Basic concept

Pile foundation systems either consist of single piles (monopiles) or a group of piles which are connected to each other by a pile cap structure. Micropiles are typically used for underpinning of civil structures, especially under limited space conditions or time constraints.
By definition, micropiles consist of tubular steel elements with an outer diameter range of approx. 60-300 mm (2.5-11.8 in).
In general, micropiles act as a passive foundation system.
Hollow bar micropiles are installed self-drilling, typically using a large-diameter drill bit. Installation is accomplished with rotary or rotary-percussive drilling equipment, depending on the ground conditions and the intended installation length.
Filling/grouting of the borehole is either performed simultaneously while drilling or afterwards. The grout serves as bonding medium which transfers the forces to the soil in terms of skin friction.
A larger grout coverage also enhances the corrosion protection of the system.

Approvals

— National technical approval in Austria (BMK)
— National technical approval in Poland (IBDiM)
— Project-specific approvals

Characteristics

— **Type and place of manufacture**
- In-situ concrete pile
- At the location of its final function

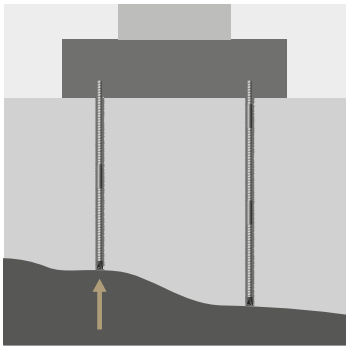
— **Installation method**
- Bored micropile
- Pile hole created by the installation process (drilling and flushing)

— **Load transfer mode**
- Bearing pile: directly onto loadable ground
- Friction pile: frictional transfer between pile casing and ground

— **Recommended corrosion protection method**
- Sacrifical
- Cement stone coverage

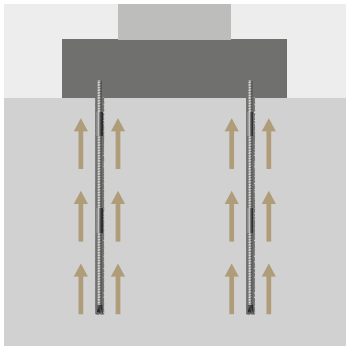
Foundation (bearing) and friction piles

End bearing piles



Foundation piles support the structure and transfer the load at the desired depth either by end bearing or skin friction.

Skin friction piles



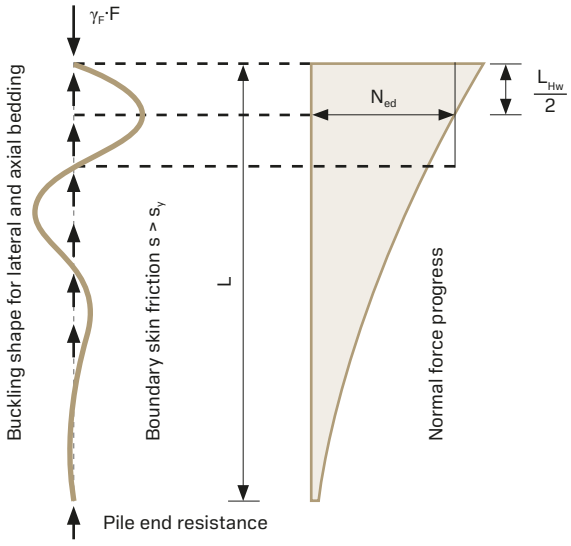
Friction piles utilize the frictional resistance force between pile surface and adjacent soil to transfer the superstructure load.

Buckling resistance (compression piles)

For the purpose of verifying the inner load-carrying capacity of micropiles, three verifications are performed accordingly:

— Normal force-bending interaction
— Limitation of horizontal deflection
— Buckling of the elastically supported pile

The micropile, potentially crossing various soil layers, is loaded by the normal design force N_{ed}. With increasing depth, the normal force decreases, i. e. the normal force is introduced continuously into the soil by skin friction. In addition to the normal force, an imperfection-induced bending moment is acting.



$$P_{cr} = \frac{\pi^2 E_p I_p}{(KL)^2}$$

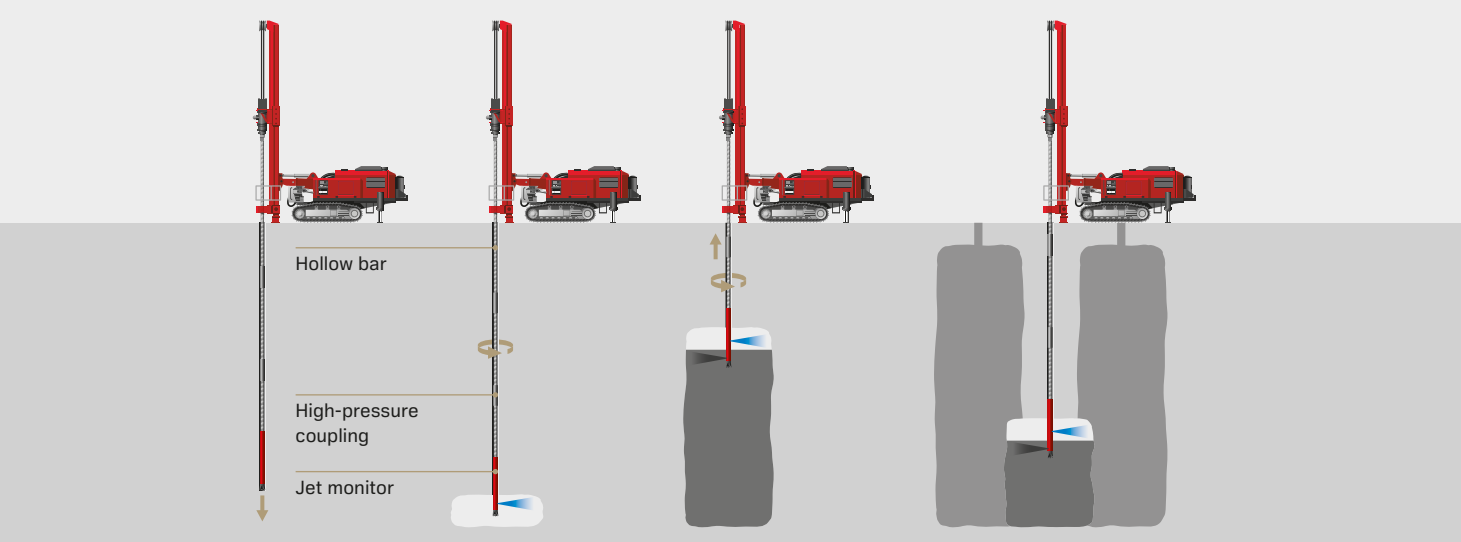
Legend:
P_{cr} = Buckling load (kN)
E_p = Young's modulus equivalent pile section (kN/m²)
I_p = Moment of inertia equivalent pile section (m⁴)
L = Length pile column without lateral support (m)
K = 1.0 for pinned ends, 0.25 for fixed ends (for the cases of cavity or slime zone), 0.7 for one fixed end and one pinned end (for the case of soft clay)

Jet grouting

Jet grouting is a common method to create a solid in-situ injection body in subsoil. Main fields of application are:

— Soil compensation
— Pile foundation
— Groundwater control
— Sealing walls
— Reinforcement of tunnel portals
— Underpinning
— Sealing bases

During the high-pressure injection (HPI) process, a hollow bar tendon in combination with an integrated jet monitor is used as injection nozzle. Installation is performed according to the self-drilling installation principle of the DSI Hollow Bar System, the only difference is the use of high-pressure couplings and injection connectors for this single fluid jet grouting operation. The hollow bar drill string with the jet monitor is installed until the intended drilling depth is reached. Then, advance (feed) is stopped and the high-pressure injection process under increased rotation speed is initiated. Injection via the jet monitor erodes the ground and creates a column of grouted soil. Consequently, the drill string is pulled outwards and inwards, to ensure development of a uniform jet grouting body.
Hollow bar jet grouting can be applied in almost any soil type, ranging from clay to coarse gravel. Size, shape, and depth of the injection body can be adjusted accordingly. The installation process is characterized by limited space requirements as well as low environmental impacts such as vibrations or ground disturbance.

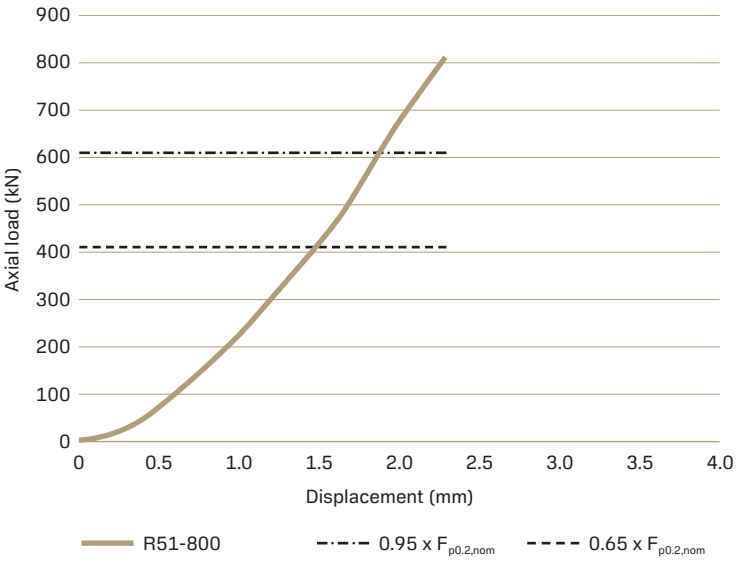


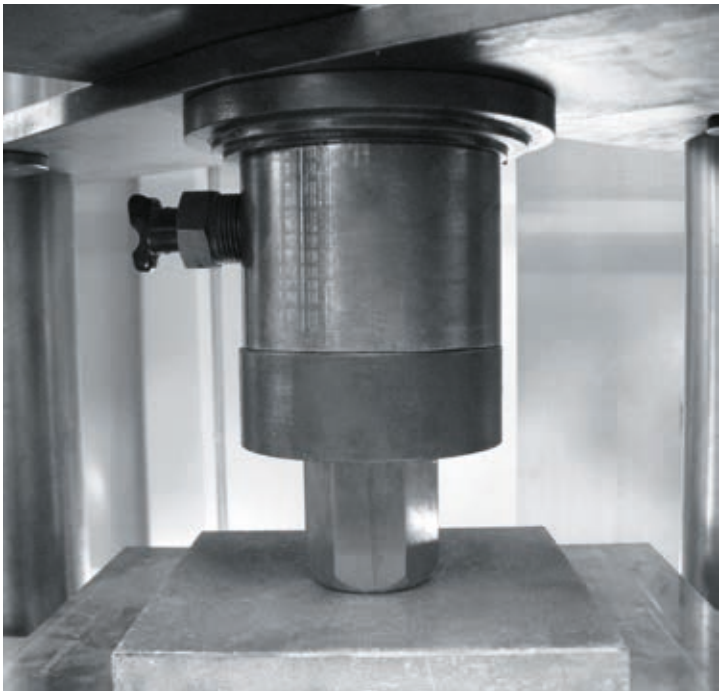
Characteristic features

Characteristic value/type [1]	R32-250	R32-400	R38-420	R38-550	R51-550	R51-925	T76-1300	T76-1900
Actual external diameter	31.1 mm	31.1 mm	37.8 mm	37.8 mm	49.8 mm	49.8 mm	74.6 mm	75.6 mm
	1.22 in	1.22 in	1.49 in	1.49 in	1.96 in	1.96 in	2.94 in	2.98 in
Delivery lengths [2]	2.0-6.0 m	2.0-6.0 m	2.0-6.0 m	2.0-6.0 m	2.0-6.0 m	2.0-6.0 m	2.0-6.0 m	2.0-6.0 m
	6.6-19.7 ft	6.6-19.7 ft	6.6-19.7 ft	6.6-19.7 ft	6.6-19.7 ft	6.6-19.7 ft	6.6-19.7 ft	6.6-19.7 ft
Modulus of elasticity	205,000 N/mm²	205,000 N/mm²	205,000 N/mm²	205,000 N/mm²	205,000 N/mm²	205,000 N/mm²	205,000 N/mm²	205,000 N/mm²
	29,700 ksi	29,700 ksi	29,700 ksi	29,700 ksi	29,700 ksi	29,700 ksi	29,700 ksi	29,700 ksi
Moment of inertia [3]	3.2 cm⁴	3.9 cm⁴	7.8 cm⁴	18.6 cm⁴	20.4 cm⁴	23.9 cm⁴	102.3 cm⁴	116.9 cm⁴
	0.08 in⁴	0.09 in⁴	0.19 in⁴	0.43 in⁴	0.49 in⁴	0.57 in⁴	2.46 in⁴	2.81 in⁴
Maximum moment (elastic) [4]	1.0 kN·m	1.5 kN·m	2.2 kN·m	2.5 kN·m	4.2 kN·m	6.2 kN·m	14.1 kN·m	19.8 kN·m
	740 lbf·ft	1,100 lbf·ft	1,625 lbf·ft	1,845 lbf·ft	3,100 lbf·ft	4,570 lbf·ft	10,400 lbf·ft	14,605 lbf·ft

1) Further technical information is included in the catalogue section “specifications”.
2) Off-size lengths are available upon request.
3) Calculated with the average internal diameter and the nominal cross-sectional area, rounded.
4) Rounded.

Load transfer testing (ETAG 013)



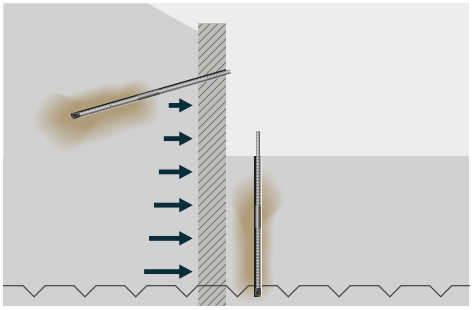


Applications

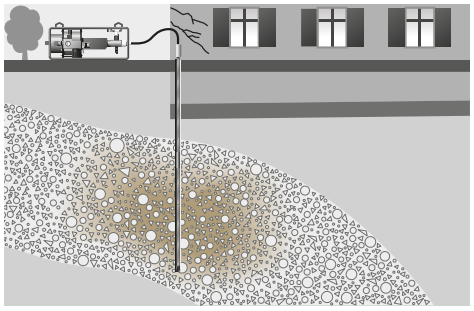
Injection lance and DSI Inject Systems

Fields of application

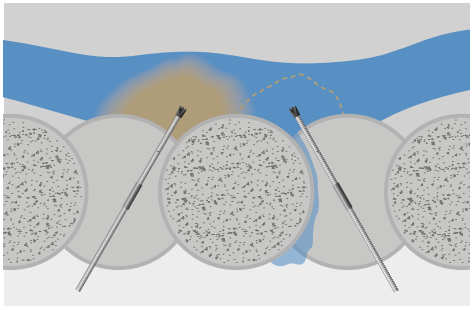
Hydraulic failure



Ground consolidation



Sealing

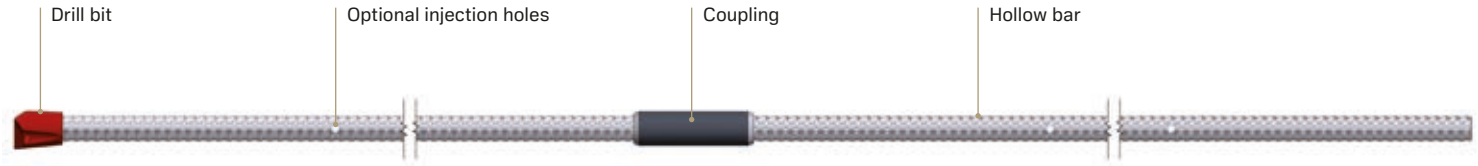


Basic concept

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 injection lances are a preferred solution to ensure a controlled, safe, and fast installation procedure.
Self-drilling injection lances allow the use of default drilling machinery; threaded hollow bars enable a durable and easy connection to any injection hose system.

DSI Inject Systems

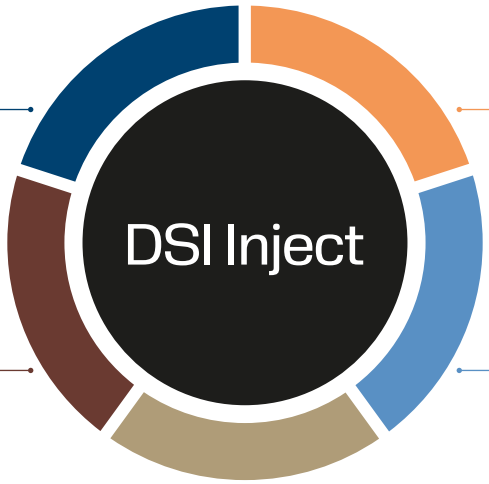
The DSI Inject product line comprises of injection resins used for civil engineering and underground applications. 2-component polyurethane systems (PUR) are the most versatile injection resin system and are mainly used for stopping water ingress and ground consolidation. 2-component silicate systems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



Full portfolio of solutions

Type	Product designation	Application							
		Water ingress	High pressure water ingress	Sealing (gas and water)	Ground stabilization	Rock stabilisation	Cavity filling	Backfilling	Bonding of rock anchors
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									
PUR (1C)	Fast and medium setting polyurethane resins	+	—	+++	++	+	—	—	—
	Slow setting polyurethane resins	—	—	+	++	++	—	—	—
Acrylic resins									
GELE (3C)	Acrylic resins	—	—	—	+++	+++	—	—	—
	Acrylic gel resins	—	—	+++	++	+	—	—	—

1) See separate brochure “DSI Inject Systems”.
“+” Recommended, “—” Not recommended.



PUR 1C
One component polyurethane resins

PUR 2C
Two component polyurethane resins

GELE 3C
Acrylic injection resins

SIL 2C
Two component silicate resins

Epoxy 2C
Epoxy resins

Specifications

SI units

Technical data series R32

Characteristic value/type [1]	Symbol	R32-250	R32-280	R32-320	R32-360	R32-400
Nominal external diameter	$D_{e,nom}$	32 mm	32 mm	32 mm	32 mm	32 mm
Actual external diameter	D_e	31.1 mm	31.1 mm	31.1 mm	31.1 mm	31.1 mm
Average internal diameter [2]	D_i	20,0 mm	18.5 mm	16.5 mm	15.0 mm	12.5 mm
Nominal cross-sectional area [3]	S_0	370 mm²	410 mm²	470 mm²	510 mm²	560 mm²
Nominal weight [4]	m	2.90 kg/m	3.20 kg/m	3.70 kg/m	4.00 kg/m	4.40 kg/m
Specific rib area	f_R	0.13	0,13	0.13	0.13	0.13
Nominal yield load [5]	$F_{p0.2,nom}$	190 kN	220 kN	250 kN	280 kN	330 kN
Nominal ultimate load [5]	$F_{m,nom}$	250 kN	280 kN	320 kN	360 kN	400 kN
Yield strength [6]	$R_{p0.2}$	510 N/mm²	540 N/mm²	530 N/mm²	550 N/mm²	590 N/mm²
Ultimate strength [6]	R_m	680 N/mm²	680 N/mm²	680 N/mm²	710 N/mm²	710 N/mm²
$R_m/R_{p0.2}$ [7]	–	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15
Ultimate load strain [7]	A_{gt}	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %
Fatigue strength $2{\cdot}\sigma_a$ [8]	–	190 N/mm²	190 N/mm²	190 N/mm²	190 N/mm²	190 N/mm²
Bond strength [9]	τ_{AK}	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²

Technical data series R38 and R51

Characteristic value/type [1]	Symbol	R38-420	R38-500	R38-550	R51-550	R51-660	R51-800	R51-925
Nominal external diameter	$D_{e,nom}$	38 mm	38 mm	38 mm	51 mm	51 mm	51 mm	51 mm
Actual external diameter	D_e	37.8 mm	37.8 mm	37.8 mm	49.8 mm	49.8 mm	49.8 mm	49.8 mm
Average internal diameter [2]	D_i	21.5 mm	19.0 mm	17.0 mm	34.5 mm	33.0 mm	29.0 mm	29.5 mm
Nominal cross-sectional area [3]	S_0	660 mm²	750 mm²	800 mm²	890 mm²	970 mm²	1,150 mm²	1,275 mm²
Nominal weight [4]	m	5.15 kg/m	5.85 kg/m	6.25 kg/m	6.95 kg/m	7.65 kg/m	9.00 kg/m	10.00 kg/m
Specific rib area	f_R	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Nominal yield load [5]	$F_{p0.2,nom}$	350 kN	400 kN	450 kN	450 kN	540 kN	640 kN	740 kN
Nominal ultimate load [5]	$F_{m,nom}$	420 kN	500 kN	550 kN	550 kN	660 kN	800 kN	925 kN
Yield strength [6]	$R_{p0.2}$	530 N/mm²	530 N/mm²	560 N/mm²	510 N/mm²	560 N/mm²	560 N/mm²	580 N/mm²
Ultimate strength [6]	R_m	640 N/mm²	670 N/mm²	690 N/mm²	620 N/mm²	680 N/mm²	700 N/mm²	720 N/mm²
$R_m/R_{p0.2}$ [7]	–	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15
Ultimate load strain [7]	A_{gt}	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %
Fatigue strength $2{\cdot}\sigma_a$ [8]	–	190 N/mm²	190 N/mm²	190 N/mm²	190 N/mm²	190 N/mm²	190 N/mm²	90 N/mm² [10]
Bond strength [9]	τ_{AK}	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²	5.1 N/mm²

Technical data series T76

Characteristic value/type [1]	Symbol	T76-1300	T76-1650	T76-1900
Nominal external diameter	$D_{e,nom}$	76 mm	76 mm	76 mm
Actual external diameter	D_e	74.6 mm	75.6 mm	75.6 mm
Average internal diameter [2]	D_i	56.0 mm	52.0 mm	47.0 mm
Nominal cross-sectional area [3]	S_0	1,590 mm²	1,975 mm²	2,360 mm²
Nominal weight [4]	m	12.5 kg/m	15.5 kg/m	18.5 kg/m
Specific rib area	f_R	0.20	0.24	0.24
Nominal yield load [5]	$F_{p0.2,nom}$	1,000 kN	1,200 kN	1,500 kN
Nominal ultimate load [5]	$F_{m,nom}$	1,300 kN	1,650 kN	1,900 kN
Yield strength [6]	$R_{p0.2}$	630 N/mm²	610 N/mm²	640 N/mm²
Ultimate strength [6]	R_m	820 N/mm²	840 N/mm²	810 N/mm²
$R_m/R_{p0.2}$ [7]	–	≥ 1.15	≥ 1.15	≥ 1.15
Ultimate load strain [7]	A_{gt}	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %

1) Status: 2021-10, all values are subject to change.
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).
8) Values are determined at an upper force $F_{up} = 0.7 \times F_{p0.2,nom}$ and 2 million load cycles.
9) Characteristic values, determined by pull-out tests using mortar with a prism compressive strength ≥ 55 N/mm².
10) Notch type according to EN 1993-1-9.

Modulus of elasticity E = 205,000 N/mm².

US customary units

Technical data series R32

Characteristic value/type [1]	Symbol	R32-250	R32-280	R32-320	R32-360	R32-400
Nominal external diameter	$D_{e,nom}$	1.26 in	1.26 in	1.26 in	1.26 in	1.26 in
Actual external diameter	D_e	1.22 in	1.22 in	1.22 in	1.22 in	1.22 in
Average internal diameter [2]	D_i	0.79 in	0.73 in	0.65 in	0.59 in	0.49 in
Nominal cross-sectional area [3]	S_0	0.57 in²	0.64 in²	0.73 in²	0.79 in²	0.87 in²
Nominal weight [4]	m	1.95 lb/ft	2.15 lb/ft	2.49 lb/ft	2.69 lb/ft	2.96 lb/ft
Specific rib area	f_R	0.13	0.13	0.13	0.13	0.13
Nominal yield load [5]	$F_{p0.2,nom}$	43 kip	49 kip	56 kip	63 kip	74 kip
Nominal ultimate load [5]	$F_{m,nom}$	56 kip	63 kip	72 kip	81 kip	90 kip
Yield strength [6]	$R_{p0.2}$	74 ksi	78 ksi	77 ksi	80 ksi	86 ksi
Ultimate strength [6]	R_m	99 ksi	99 ksi	99 ksi	103 ksi	103 ksi
$R_m/R_{p0.2}$ [7]	–	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15
Ultimate load strain [7]	A_{gt}	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %
Fatigue strength $2{\cdot}\sigma_a$ [8]	–	28 ksi	28 ksi	28 ksi	28 ksi	28 ksi
Bond strength [9]	τ_{AK}	0.7 ksi	0.7 ksi	0.7 ksi	0.7 ksi	0.7 ksi

Technical data series R38 and R51

Characteristic value/type [1]	Symbol	R38-420	R38-500	R38-550	R51-550	R51-660	R51-800	R51-925
Nominal external diameter	$D_{e,nom}$	2.01 in	2.01 in	2.01 in	2.01 in	2.01 in	2.01 in	2.01 in
Actual external diameter	D_e	1.49 in	1.49 in	1.49 in	1.96 in	1.96 in	1.96 in	1.96 in
Average internal diameter [2]	D_i	0.85 in	0.75 in	0.67 in	1.36 in	1.30 in	1.14 in	1.16 in
Nominal cross-sectional area [3]	S_0	1.02 in²	1.16 in²	1.24 in²	1.38 in²	1.50 in²	1.78 in²	1.98 in²
Nominal weight [4]	m	3.46 lb/ft	3.93 lb/ft	4.20 lb/ft	4.67 lb/ft	5.14 lb/ft	6.05 lb/ft	6.72 lb/ft
Specific rib area	f_R	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Nominal yield load [5]	$F_{p0.2,nom}$	79 kip	90 kip	101 kip	101 kip	121 kip	144 kip	166 kip
Nominal ultimate load [5]	$F_{m,nom}$	94 kip	112 kip	124 kip	124 kip	148 kip	180 kip	208 kip
Yield strength [6]	$R_{p0.2}$	77 ksi	77 ksi	81 ksi	74 ksi	81 ksi	81 ksi	84 ksi
Ultimate strength [6]	R_m	93 ksi	97 ksi	100 ksi	90 ksi	99 ksi	102 ksi	104 ksi
$R_m/R_{p0.2}$ [7]	–	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15	≥ 1.15
Ultimate load strain [7]	A_{gt}	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %
Fatigue strength $2{\cdot}\sigma_a$ [8]	–	28 ksi	28 ksi	28 ksi	28 ksi	28 ksi	28 ksi	13 ksi [10]
Bond strength [9]	τ_{AK}	0.7 ksi	0.7 ksi	0.7 ksi	0.7 ksi	0.7 ksi	0.7 ksi	0.7 ksi

Technical data series T76

Characteristic value/type [1]	Symbol	T76-1300	T76-1650	T76-1900
Nominal external diameter	$D_{e,nom}$	3.0 in	3.0 in	3.0 in
Actual external diameter	D_e	2.94 in	2.98 in	2.98 in
Average internal diameter [2]	D_i	2.20 in	2.05 in	1.85 in
Nominal cross-sectional area [3]	S_0	2.46 in²	3.06 in²	3.66 in²
Nominal weight [4]	m	8.40 lb/ft	10.42 lb/ft	12.43 lb/ft
Specific rib area	f_R	0.20	0.24	0.24
Nominal yield load [5]	$F_{p0,2,nom}$	225 kip	270 kip	337 kip
Nominal ultimate load [5]	$F_{m,nom}$	292 kip	371 kip	427 kip
Yield strength [6]	$R_{p0,2}$	91 ksi	88 ksi	93 ksi
Ultimate strength [6]	R_m	119 ksi	122 ksi	117 ksi
$R_m/R_{p0.2}$ [7]	–	≥ 1.15	≥ 1.15	≥ 1.15
Ultimate load strain [7]	A_{gt}	≥ 5.0 %	≥ 5.0 %	≥ 5.0 %

1) Status: 2021-10, all values are subject to change.
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).
8) Values are determined at an upper force $F_{up} = 0.7 \times F_{p0.2,nom}$ and 2 million load cycles.
9) Characteristic values, determined by pull-out tests using mortar with a prism compressive strength ≥ 8 ksi.
10) Notch type according to EN 1993-1-9.

Modulus of elasticity E = 29,700 ksi.

Corrosion protection

Definitions, principle, and protection

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

Corrosion of concrete
This principle applies for grout and cement mortar. Three main factors of concrete corrosion are pH-value, presence of oxygen, and ion concentration. Concrete damage on the surface is a first requirement for the penetration of harmful substances as far as the reinforcement in the concrete is located. Subsequently, the corrosion of reinforcing elements reduces the strength of the structure. Dense and impenetrable concrete is more protected against corrosion than a porous one.

Corrosion of the reinforcement in the concrete
In properly fabricated reinforced concrete structures, reinforcement elements are generally not subjected to corrosion. Hence, if an adequate gas and water permeability of the concrete through cracks occurs, air containing carbon dioxide, sulfides, or corrosive water in general can be transferred to the reinforcement, causing steel corrosion to start. For civil engineering applications, where a proper and complete cement stone or grout cover cannot be guaranteed in many cases, the sacrificial corrosion principle is a recommended tool for the design of ground control systems with an extended service life. Hence, a cement stone coverage and respective carbonation generally helps to reduce the corrosion rate.

Corrosion protection methods

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

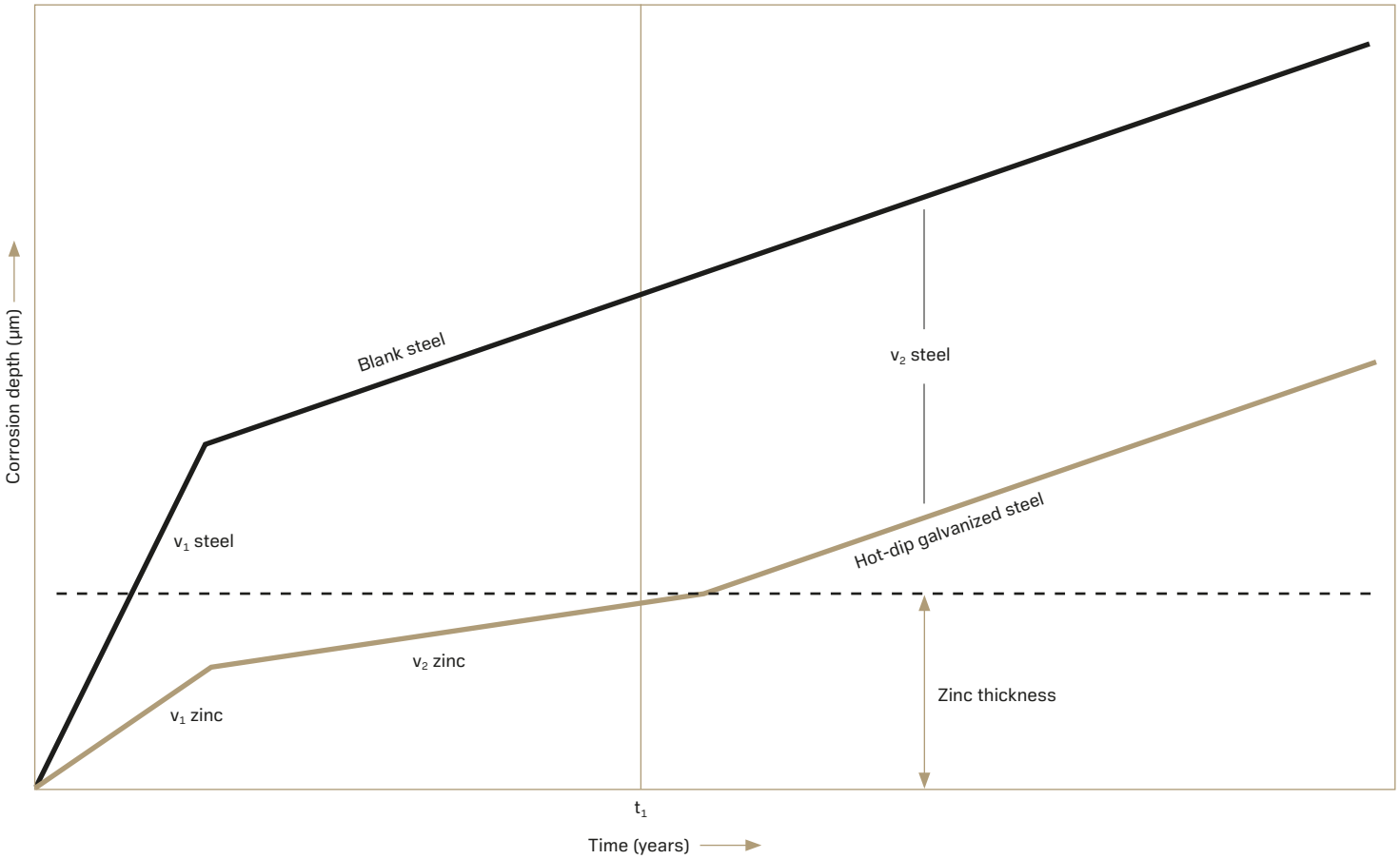
Sacrificial corrosion protection
— Definition of corrosion rates (sacrificial corrosion), depending on ground conditions and other influencing factors
— Element design in accordance with an increase of cross-section due to corrosion over the intended service life
— The system inherent encapsulation with 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 for different corrosion loads [3]		
		Low	Medium	High
2 years	Blank	0 mm	0 mm	0.2 mm
	Hot-dip galvanized	0 mm	0 mm	0.1 mm
7 years	Blank	0.2 mm	0.2 mm	0.5 mm
	Hot-dip galvanized	0 mm	0.1 mm	0.4 mm
30 years	Blank	0.3 mm	0.6 mm	–
	Hot-dip galvanized	0.1 mm	0.4 mm	–
50 years	Blank	0.5 mm	1.0 mm	–
	Hot-dip galvanized	0.3 mm	0.7 mm	–

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-dip galvanized steel in soil (ETA-21/0869) [1]



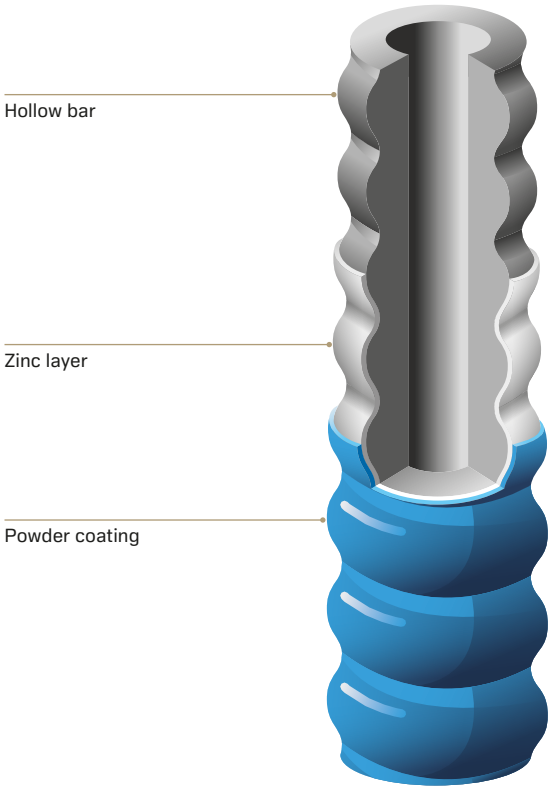
1) Prof. Dr.-Ing. Habil. Prof. H.C. Ulf Nuernberger, expertise “Korrosionstechnische Beurteilung des DSI Hohlstab-Systems fuer Bodennnaegel, Pfaehle und Erdanker”.

Duplex coating

Introduction
According to EN ISO 12944-5, duplex systems are understood to be a corrosion protection system which consists of galvanizing in combination with one or more subsequent coatings.
The corrosion protection working mechanism of duplex systems is based on mutual protection of the partners. Protected by the powder coating, the zinc layer remains intact for an extended time period.

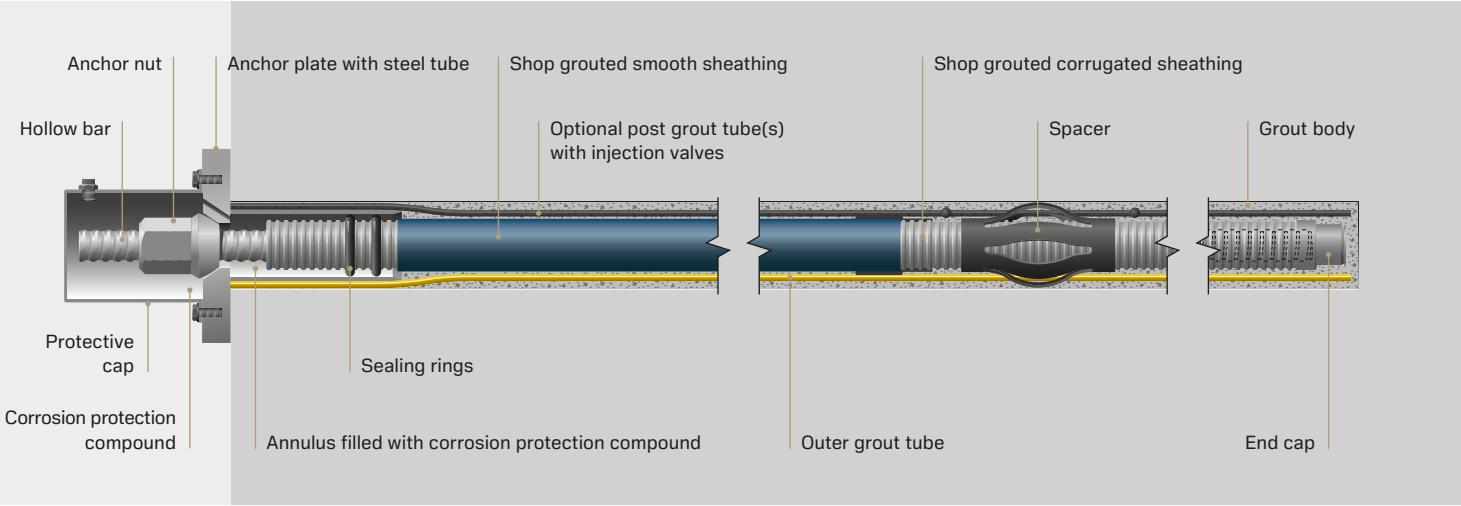
Technical features
— Duplex system according to EN ISO 12944-5
— Coating system according to corrosion category C5-M
— In different coating colors (standard: blue) available
— Hot-dip galvanization according to EN 1461
— Accessories designed to the respective highest load capacity
  - R32-400
  - R38-550
  - R51-800 (R51-925)
  - T76-1900

Main advantages
— Improved corrosion protection, resulting in a longer lifespan
— Synergism effect: adjusting extension factor of the service life of up to 2.5 times
— High resistance to abrasion



Double corrosion protection

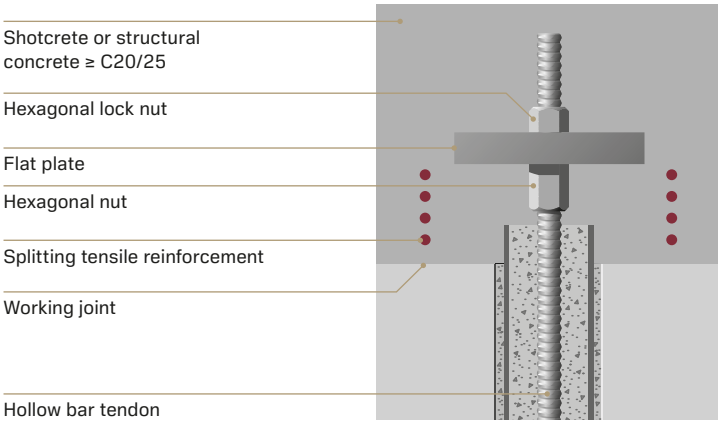
— Factory-made corrugated sheathing
— Controlled crack width
— Not applicable for self-drilling installation
— Installation into pre-drilled boreholes and post-injection



Cement stone coverage

— Encapsulation of load-bearing elements
— Carbonation reduces the influence of corrosive environments
— Guaranteed full encapsulation and limitation of crack development required for a successful application of this method

Pile head construction (compression pile)



Reference values minimum cement stone coverage for micropiles [1]

Exposure class [2]	Chemical aggressiveness	Bearing element with grout cover		Bearing element with mortar	
		Compression	Tension	Compression	Tension
X0	With permanent casing	10 mm	10 mm	25 mm	25 mm
X0, XC1-XC4	Not existing	20 mm [3]	20 mm [3]	35 mm	40 mm
XD1, XD2	Chloride except salt water	20 mm	20 mm	35 mm	40 mm
XS1	Chloride from salt water	20 mm	20 mm	35 mm	40 mm

1) OENORM EN 14199:2016 – Execution of special geotechnical works – Micropiles.
2) For other exposure classes in EN 206, minimum cement stone coverage values are given in EN 1992–1-1:2004, clause 4, and the valid national annex.
3) For service life of maximum 5 years the minimum grout cover may be reduced to 10 mm.

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

		Drill bit type [1]									
Diameter [1]	**Thread**	**Two-stage R-flush (retro flush), hardened**	**Two-stage RS-flush (retro and 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 mm (2.0 in)	R32					X	X	X	X	X	X
	R38										
	R51										
	T76										
76 mm (3.0 in)	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 mm (3.5 in)	R32			X	X						
	R38			X	X			X	X	X	X
	R51			X	X			X	X	X	X
	T76										
100 mm (3.9 in)	R32		X								
	R38		X							X	X
	R51							X	X	X	X
	T76										
115 mm (4.5 in)	R32										
	R38			X	X			X	X	X	X
	R51			X	X			X	X	X	X
	T76							X	X		
130 mm (5.1 in)	R32										
	R38		X								
	R51			X				X	X	X	X
	T76	X		X	X			X	X	X	X
150 mm (5.9 in)	R32										
	R38										
	R51		X								
	T76	X		X	X			X		X	X
200 mm (7.9 in)	R32										
	R38										
	R51										
	T76	X						X	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 120-150 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:

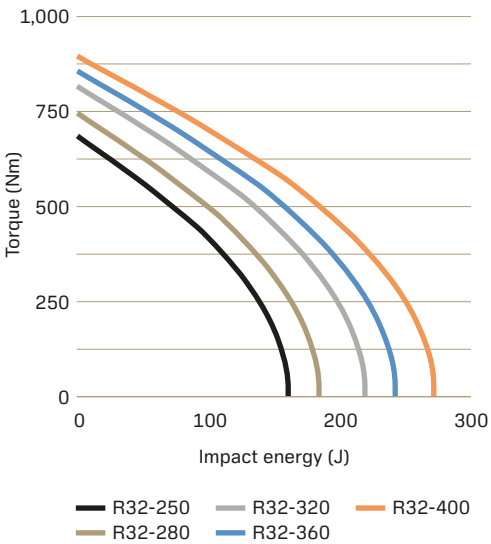
— Amount and type of flushing medium
  - Air, water, water-air mixture, or grout
  - Simultaneous drilling and grouting is a combined flushing and injection technique
— Ground conditions
  - Non-binding soils or fractured rock result in an increased consumption of injection media
— Water-cement ratio
  - Generally between 0.35 and 0.70

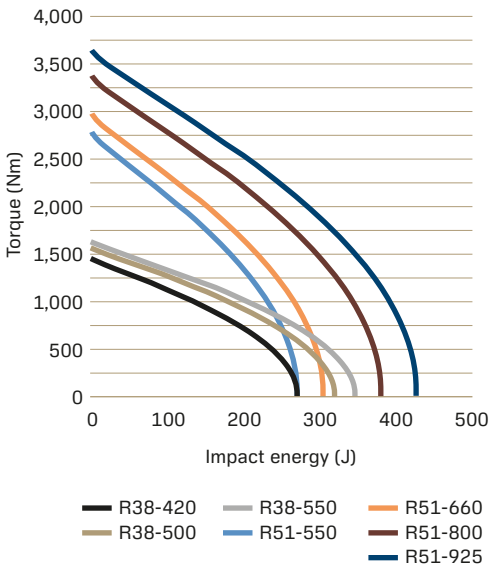
Besides the common self-drilling installation feature, grouting may either be performed while drilling with a rotary injection adapter or after the drilling operation. This subsequent grouting procedure is accomplished with a conical push adapter or a threaded coupling connector. In case given ground 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.

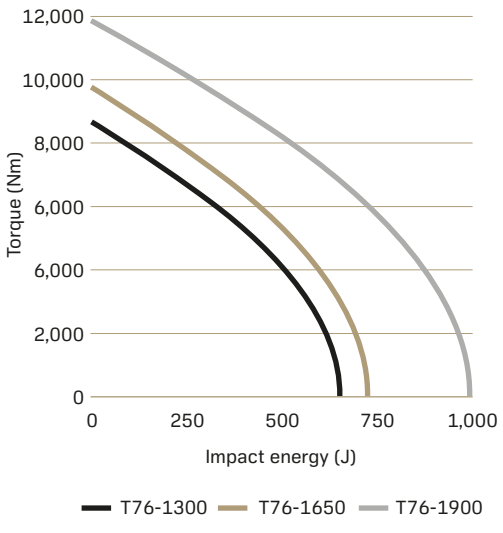
Simultaneous drilling and grouting

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



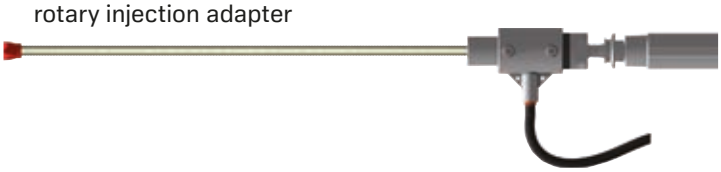




Installation methods

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 rock 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

Testing and monitoring

Introduction

On-site testing ensures proper functioning and allows to proof the performance of the installed DSI Hollow Bar System. Depending on the application, an appropriate test method must be selected. Tests are carried out on trial elements. Those trial elements should be prepared and installed as performed during the construction process.
For example, testing of ground anchors involves three general testing types for quality control purposes:

Investigation tests
— Conducted on trial anchors installed prior to the main works
— Investigation tests provide information on the expected performance of working anchors, suitability of design, and levels of safety

Suitability tests
— Conducted on ground anchors identical to the working anchors
— Data provides a reference against which the performance of the working anchors can be measured

Acceptance tests
— May be applied to all working anchors
— Test loading demonstrates the ground anchor's ability to withstand a load exceeding its working load

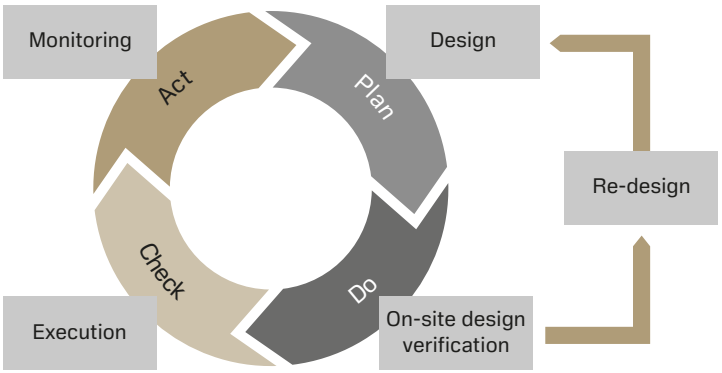
For micropiles as well as rock and soil nails, investigation tests and suitability tests are the preferred testing types. In the course of investigation tests, the ultimate load resistance at the ground-grout interface and the characteristics of the system in the working load range are determined. Suitability tests confirm a particular design in comparable ground conditions by test loading.
Pull-out tests are the default on-site testing procedure for ground anchors, soil nails, and bolts. Depending on the loading mechanism (tensile, compressive, or alternating), micropiles are tested either by pull-out tests and/or static load tests.
Spiles and injection lances are generally not tested in-situ.
Testing and monitoring feature economic advantages during the product service life cycle. With the information from in-situ tests at hand, an optimization of the construction design may be possible.
Monitoring and regular inspection increase the service life of both the used product and the entire structure, because structural damages or imperfections of construction can be detected at an early stage.

Pull-out tests

A pull-out (or simply pull) test measures the characteristics and the performance of the load transfer mechanism of the installed DSI Hollow Bar System.
Pull tests can be conducted on actual lengths (soil nails) or on short encapsulated samples. At the excess length of the installed hollow bar, a tensile load is applied by using a hydraulic tension jack with a load measurement system.
A hydraulic hollow core cylinder and a press chair as bearing on the soil or rock surface are connected to the hollow bar with a pull adapter and fixing nut. Tensile loading is applied over the extension of the hollow core cylinder. During pull-out tests, force and displacement of the hollow bar must be measured and recorded.
In general, pull test equipment includes the following main parts:

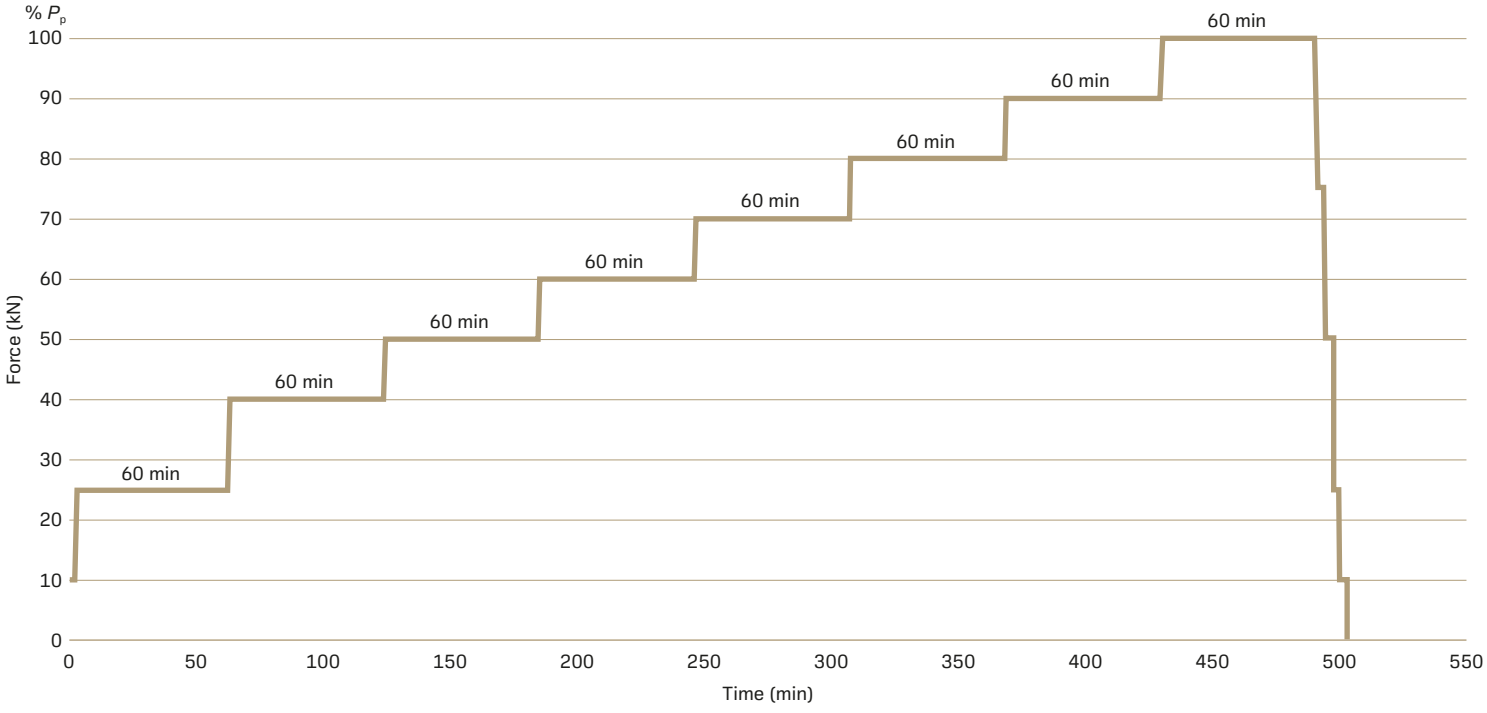
— Tension adapter, pull rod, and fixing nut
— Press chair (bearing element)
— Hydraulic system: hollow core cylinder and pump
— Load and displacement measurement systems

Further information regarding pull testing equipment is included in the catalogue section "system accessories".



Applications

Pull-out test – acceptance test according to ISO 22477-5 (test method 3)



Load cell KMD

Key features
— Load cells for 800 to 10,000 kN nominal force
— Nominal force is equivalent to constant force
— 30 % overload for a short time
— Elastic element from stainless steel
— Can be used in aggressive, acid-, and chloride-containing environments such as road tunnels and bridge undersides
— Protection class IP 68
— Integrated temperature sensor
— Integrated signal amplifier
— Insensitive to long cable lengths and electrical interference
— Measuring signal in V and mV/V
— Automatic identification of the load cell using the integrated memory for registration of site, cell number, date of installation, etc.
— Durable UV-, acid-, and oil-resistant signal cables
— Durable, waterproof LEMO connector
— Optional overvoltage protection
— Arbitrary cable length

Readout device
— Portable read-out device
— 4-line display
— Display of cell force and cell temperature
— Display of the serial number of the KMD
— Display of cell ID, site, etc., as entered by the user
— Force resolution 1 kN
— Temperature resolution 0.5 °C
— Operating temperature -25 to 50 °C
— Powered using rechargeable Li-ion battery, external battery charger
— Dimensions 216 x 180 x 102 mm
— Weight < 2 kg
— Housing made of special high-impact plastic
  - Airworthy
  - Shock-resistant
  - Break-proof
  - Waterproof IP 67
  - Sand- and dust-proof
  - Airtight
  - Acid-resistant
  - Pressure-resistant

SMART DSI Hollow Bar System

Introduction

The DSI Hollow Bar System is an ideal type of tendon used for measuring bolts, both underground and for civil engineering applications. The system is standardized, flexible in length, and can accommodate a measuring device inside the hollow bar. Conventional tunneling measuring bolts consist of a fully grouted hollow bar tendon including a multi-rod extensometer inside the hollow core of the bolt, which is used to measure relative displacements between anchorage points along the tendon length. Those systems are pre-assembled and installed in one piece intro pre-drilled boreholes. Hence, the maximum length of conventional measuring bolts is therefore limited to the open span available for installation. Furthermore, this measuring bolt is limited to the function of extensometer readout data.

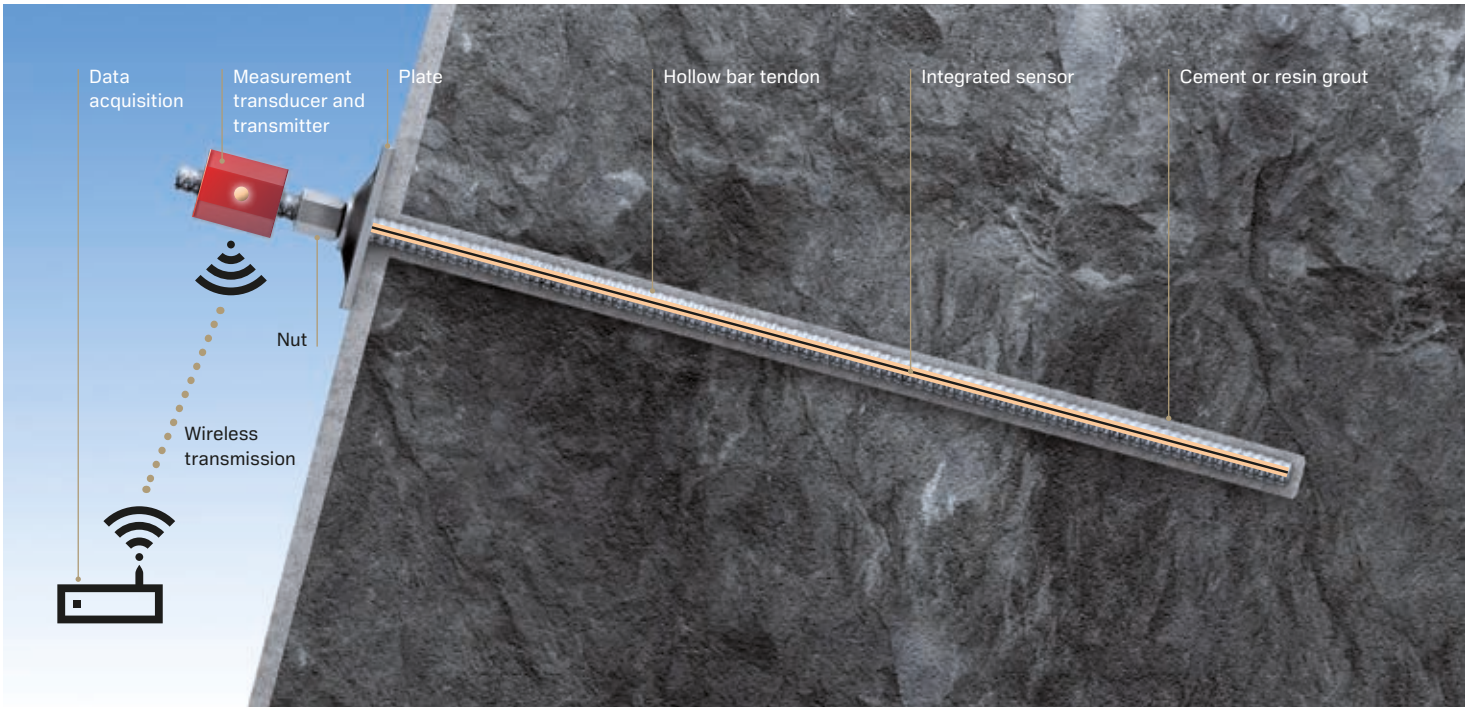
A new generation of a SMART DSI Hollow Bar System which is currently under development is designed to bring digitalization in construction to a new level. Installation can be accomplished self-drilling and in the same way as for the default DSI Hollow Bar System, laying the foundation for a fast and effective application. Hollow bar tendons are equipped with integrated sensors, protected from the construction environment.

A supplementary SMART nut with integrated additional geotechnical and environmental sensors extends the measurement capability of the system. The SMART nut also features as measurement transducer and wireless transmitter.

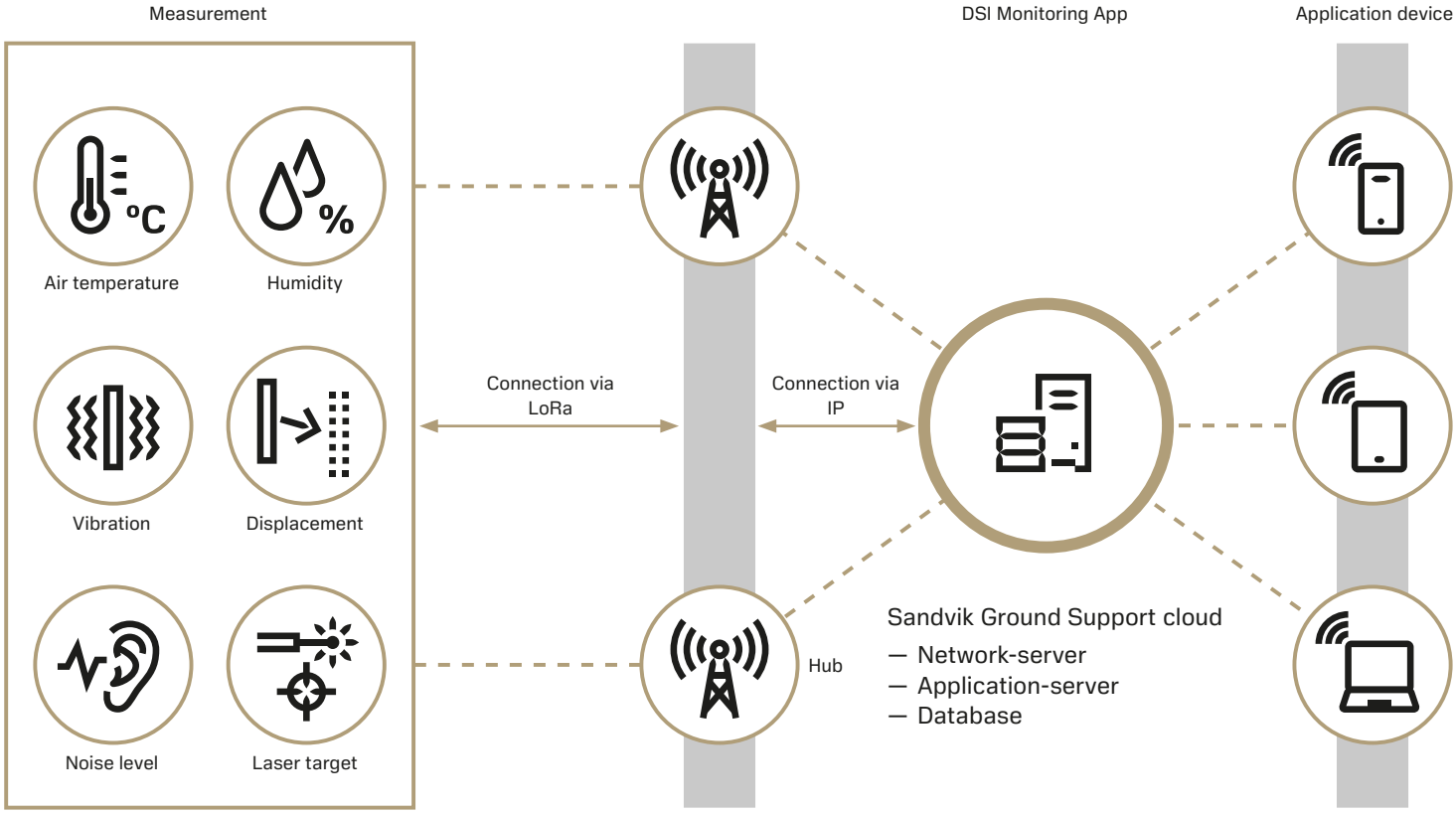
Data acquisition can be accomplished with existing data loggers, the system is designed to be open-source and compatible with state-of-the-art software applications. The SMART DSI Hollow Bar System enables a seamless transformation from a conventional bolt application to an intelligent (sensor-equipped) tool, without changing its basic configuration and support characteristics.

Based on the magnitude of environmental and geotechnical data acquired, applications in design and life cycle management are unlimited. DSI Underground is looking forward to present the SMART DSI Hollow Bar System soon.

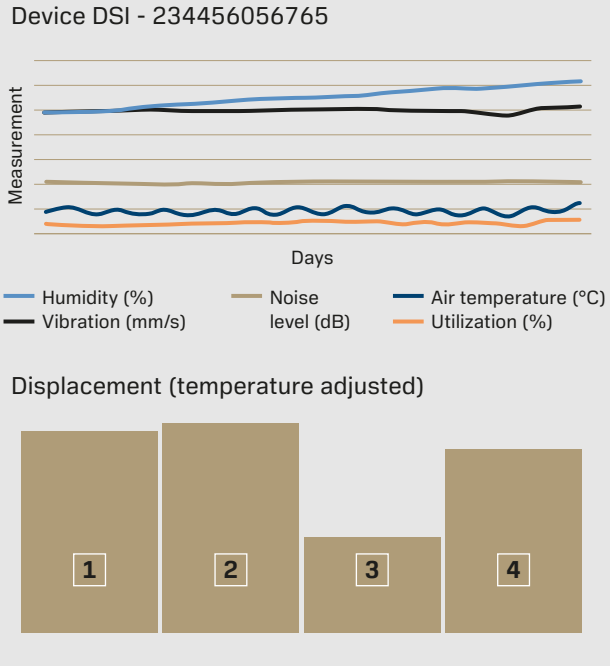
Digital bolt



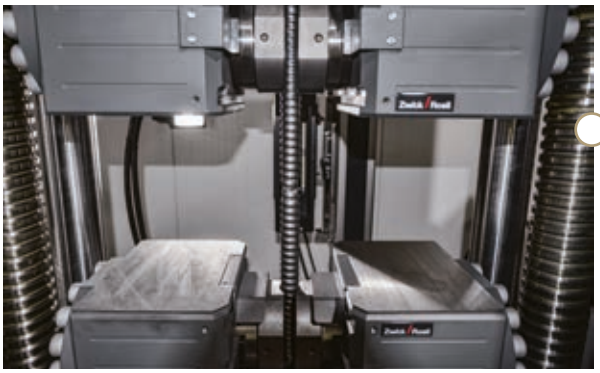
DSI monitoring applications (data transmission)



Georeferenced visualisation



Closed-loop strategy

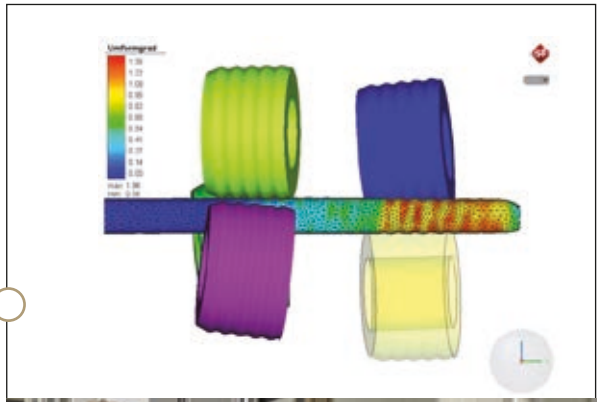


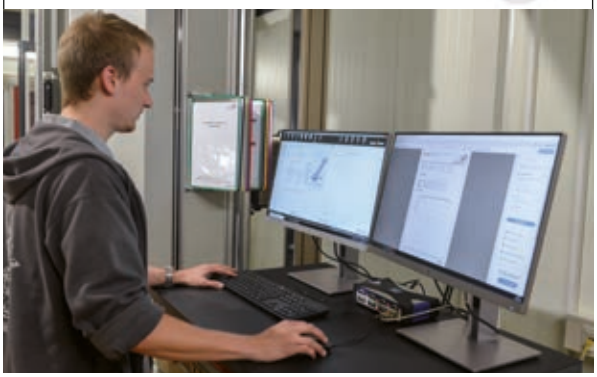
Sales

Marketing

Research and development

Production scheduling





Production scheduling

Technical order generator

Production sequencer

Capacity planner

Smart rescheduler

System accessories

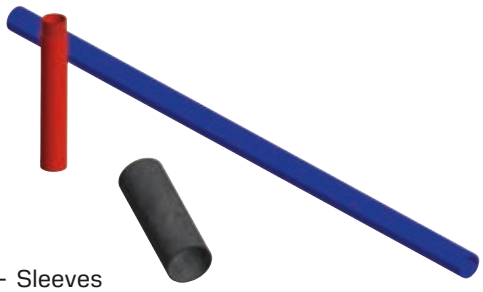
Sandvik Ground Support provides a wide range of modular system accessories, which complete the premium quality series of the DSI Hollow Bar System. System accessories are essential for a safe and successful product performance. Typical system accessories can be used as structural load-bearing elements and for drilling, grouting, and monitoring. Local support and short-term availability is provided by local competence centers – Sandvik Ground Support is **the solution provider.**

— Yielding anchor head
— Angle compensation disks
— Reverse anchor head
— Protective caps
— Anchorage and foundation elements

— Bayonet connector

— Post-injection coupling

— Utility nuts



— Sleeves

— Injection flow-pressure meter

— Grout mixing pump

— Post-injection adapter
— Rotary injection adapter

— Load cell KMD

— Drill rod wrench
— Rock drilling equipment

— Pull testing equipment

— Sealing coupling

— S-D expansion bolt

— Expansion shell

— Lock coupling

— Centralizer

— Drill bit adapters

— Drill bits

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 to ensure 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 hollow bar 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 hollow bar principle with a robust and innovative expansion element.
The hollow bar 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.
The hollow bar 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

— Self-drilling 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 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 to 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 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 de-coupling of 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

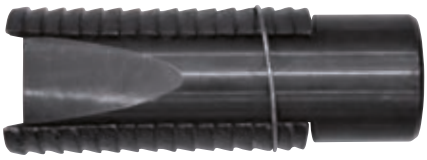
Expansion shell

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 type 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



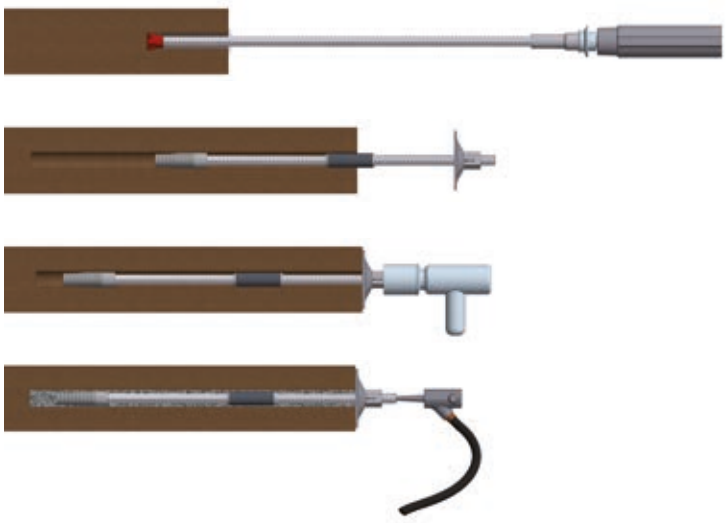
Specifications

Characteristic value/type	Symbol	SK-R32-048	SK-R38-068	SK-R51-078
Nominal external diameter	$D_{e,nom}$	48 mm (1.9 in)	68 mm (2.7 in)	78 mm (3.1 in)
Length	L	170 mm (6.7 in)	186 mm (7.3 in)	230 mm (9.1 in)
Nominal weight	m	1.8 kg (4.0 lb)	4.0 kg (8.8 lb)	7,8 kg (17.2 lb)
Required borehole diameter	D_b	52-58 mm (2.0-2.3 in)	72-78 mm (2.8-3.1 in)	90-95 mm (3.5-3.7 in)
Nominal load-bearing capacity [1)]	$F_{m,nom}$	230 kN (52 kip)	400 kN (90 kip)	630 kN (142 kip)

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
— nsertion 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

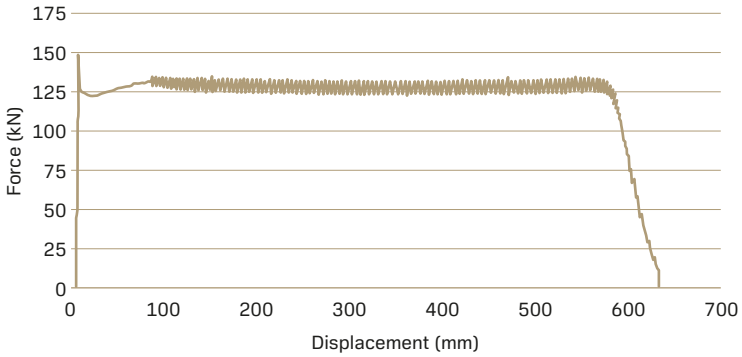
— Controlled accommodation of large deformations
— Adjustable to given ground conditions
— Constant high yielding force level
— Tough and durable design
— German approval for underground application
— Simple and secure manipulation of pre-assembled components

Specifications

Characteristic value/type	R32-GK 150-L [1]
Yield force	130-150 kN (29-34 kip)
Yield length	Bis zu 600 mm (23.6 in)

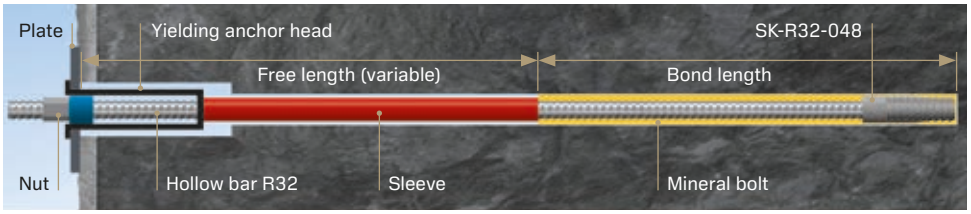
1) Recommended default hollow bar type: R32-360.

Yielding characteristics



Basic concept

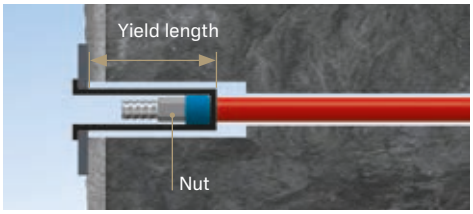
Installation principle



— 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

Working mechanism



— Yielding anchor head
  - Discrete component
  - Absorbing mechanism based on a cylinder with integrated piston
  - Defined force-displacement characteristics
  - Adjustable to project-specific requirements

Lock coupling

Introduction

The lock coupling secures an easy-to-remove temporary bolt or anchor construction with a free length. Use of a lock coupling prevents disconnection of hollow bars due to clockwise rotation in the course of drill string extension.
Faulty installation may be caused by worn out coupling adapters, damaged or missing clamping jaws, or loose couplings if non system-conform components have been used. The lock coupling prevents a loosening of couplings inside the borehole – the hollow bar is installed continuously in one piece.

Main advantages

— The lock coupling does not detach itself during a clockwise rotation of the drill string
— Trouble-free extension or de-coupling of the drill string
— Suitable for free length sections
— Controlled removal of defined hollow bar sections by the selective use of standard couplings and lock couplings

System description

The standard coupling is replaced by a lock coupling. During the counterclockwise rotation of the drill string, the inside locking mechanism (toothed gear with radial and longitudinal teeth) cuts transverse ribs onto the hollow bar. Thus, the hollow bar coupling is locked against clockwise rotation and loosening.

Specifications

— Available for series R32, R38, and R51
— Designed for highest load-bearing capacities
  - R32-400
  - R38-550
  - R51-800 (R51-925)
— Optionally available with a one-sided or double locking mechanism

Technical features

— Handling during installation is the same as for standard couplings
— The lock coupling permits rotary-percussive installation (counterclockwise) and locks the coupling during clockwise rotation of the drill string

Sealing coupling

Introduction

Due to the design of conventional couplings for standard applications, absolute leak tightness of the couplings cannot be warranted when applying standard flushing pressures.
The sealing coupling allows an optimized installation procedure with regards to the leak tightness of the drill string.
This advantage is significant for simultaneous drilling and injection operations.

Main advantages

— Targeted and safe injection of the flushing and/or injection medium
— Sealing couplings ensure leak tightness when applying standard flushing pressures
— Easy application; same operating principle as for standard couplings

System description

The standard coupling is replaced by a sealing coupling. Upon establishment of a proper and tight connection, the pre-installed centered sealing ring ensures a tight fitting between the chamfered surfaces of two hollow bars. During installation and injection, the sealing coupling ensures a tight connection under default working pressures.

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

Technical features

— Handling during installation is the same as for standard couplings
— A sealing ring inside the coupling and chamfered hollow bar ends ensures optimal leak tightness

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 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 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

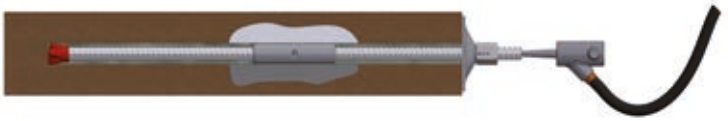
— Available for series R32, R38, R51, and T76
— Designed for highest load-bearing capacities
  - R32-400
  - R38-550
  - R51-800 (R51-925)
  - T76-1900
— Factory-set adjustable rated valve opening pressure: from 8 to 20 bar (115 to 290 psi)
— Integrated non-return function

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 primary injection, depending on the grout mixture used (generally 12 to 18 hours)
  - Post-injection with an injection adapter through the post-injection couplings with a pressure exceeding 8 bar (115 psi)
  - Maximum injection pressure depending on application and ground conditions
  - Repetition of working steps in case a consecutive injection process is required
  - Preparation of the head construction, if required

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



Utility nuts

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

Bail nut

— Light utility hangers
— Mounting of instrumentation tools

Anchorage elements

Sleeves

— De-bonding
— Free length(s)
— Additional corrosion protection
— Micropiles: pile neck reinforcement
— Steel and plastic versions available

Protective caps

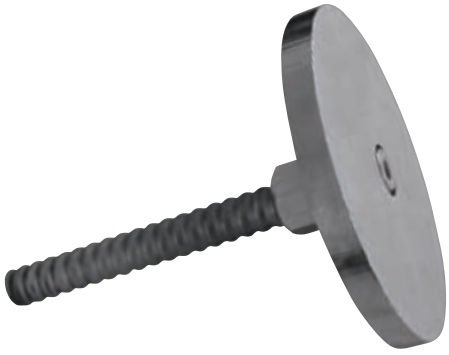
— Temporary corrosion protection
— Construction walls where shotcrete is not used for sealing
— Protection of personnel when head constructions are exposed to walkways
— Steel and plastic versions available

Angle compensation disks

— Secure anchorage even for large inclinations (<= 55°)
— Standard application in combination with domed nuts
— Standard version for hollow bar series R32 and R38

Reverse anchor head

— Sheet piles
— Tie-back anchorage
— Limited space conditions



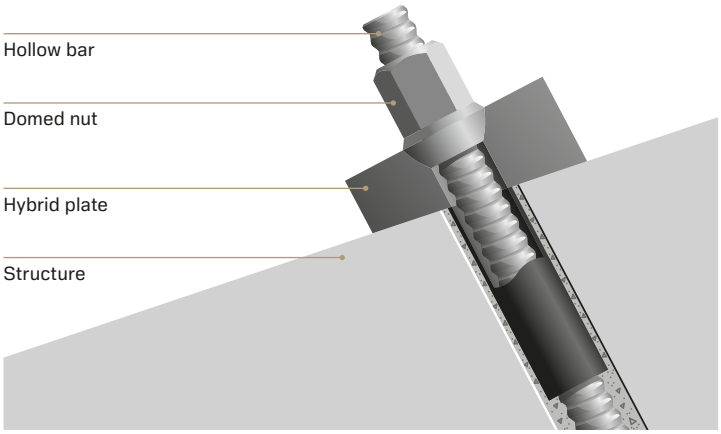
Hybrid plate

Introduction

Hybrid plates are made of fiber reinforced ultra-high performance concrete and used for the anchorage of tendon forces.
The functionality of hybrid plates has been verified by testing according to EAD-160004-00-0301 (post-tensioning kits for prestressing of structures – former ETAG 013).

Main advantages

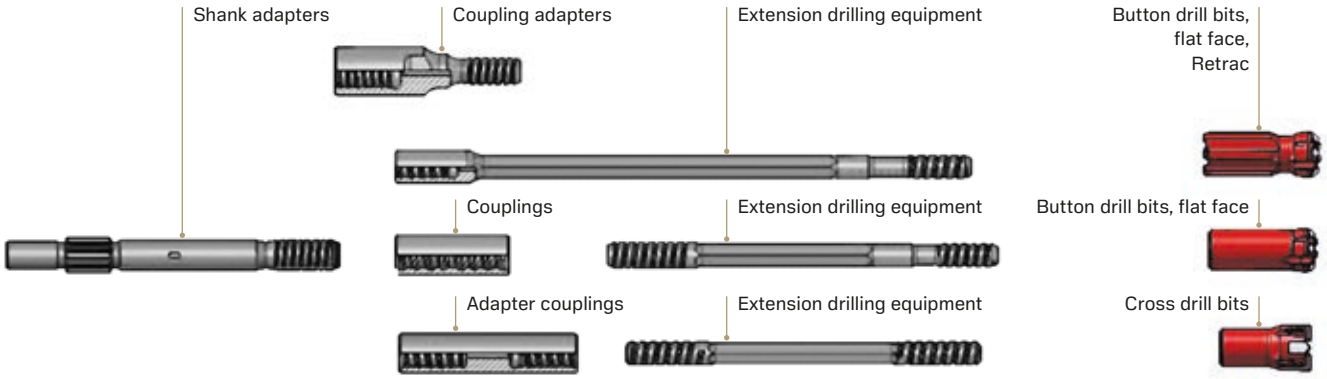
— Enhanced corrosion protection and durability
— Adjustable geometry
— Low weight
— Angle compensation up to 30°
— Custom-specific solutions
  - Threaded sleeves for connection of a cap
  - Inlets for grouting and ventilation lines
  - PE connection pipes for corrosion protection



Rock drilling equipment

System components

— Shank adapters
— Couplings
— Adapter couplings
— Extension drilling equipment
— Coupling adapters
— Drill bits
  - Drill bits in either flat face or Retrac design



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

Drill rod wrench and tensioning tool

— Tough design
— Various lengths and wrench sizes

Bayonet connector

The bayonet connector is a sealed, easy-to-remove connection between hollow bars used for self-drilling installation. It consists of two parts: adapter and coupling. A bayonet connector efficiently transfers the impact energy and torque from the hydraulic drifter or rotary head onto the hollow bar drill string.
Defined hollow bar sections can be easily removed once drilling has been completed.

— Sealed connection for micropile installation
— Easy to disconnect
— Removal of defined hollow bar sections
— Transfer of the drilling energies nearly without any loss

Centralizers

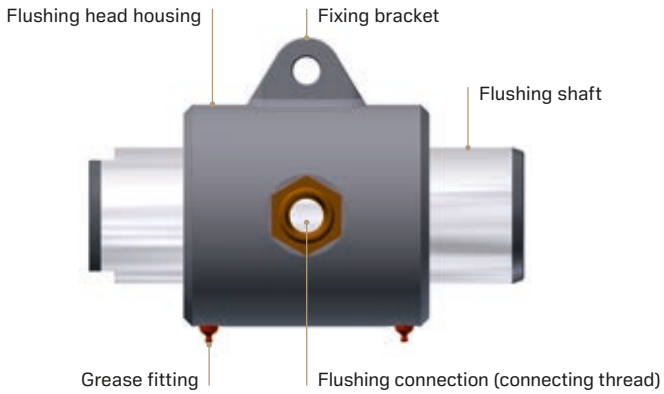
— Centralization of hollow bars inside the borehole
— Increased directional installation accuracy
— Optimum grout cover
— Available for series R32, R38, R51, and T76

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
— High 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

DSI MAI® grout mixing pumps

Introduction

DSI MAI® grout mixing pumps have been developed for extremely challenging 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 civil engineering and 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
— Low 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

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 and rock	XXX	XXX	X	XXX	—	—
		Void filling	XXX	XXX	X	XXX	—	—
		Hollow bars	XXX	XXX	X	XXX	—	—
Mining	Cement, anchor mortars, premixed grouts	Hollow bars	—	—	—	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	DSI MAI® 400 EASY PLUS	DSI MAI® 400 NT	DSI MAI® 440 GE
Nominal power	4.0 kW	6.2 kW	10.0 kW
	5.4 hp	8.3 hp	13.4 hp
Gear motor	290 rpm	200 rpm	200 rpm
Delivery rate	16 l/min	8-34 l/min	5-54 l/min
	4.2 gal/min	2.1-9.0 gal/min	1.3-14.3 gal/min
Operation pressure	25 bar	40 bar	40 bar
	360 psi	580 psi	580 psi
Length	1,616 mm	1,755 mm	2,010 mm
	63.5 in	69.1 in	79.1 in
Width	580 mm	570 mm	750 mm
	23 in	22 in	30 in
Height	900 mm	960 mm	1,030 mm
	35 in	38 in	41 in
Filling height	900 mm	960 mm	1,030 mm
	35.4 in	38 in	41 in
Total weight	136 kg	230 kg	360 kg
	300 lb	507 lb	794 lb

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.

System description

Flow rates and injection pressures are recorded separately for each injection borehole. The manipulation-proof digital data recording is operated via a 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.

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 the 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 m^3/h (140/425 ft^3/h)

Further references

— **EN 1461**
Hot-dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods

— **EN 12501-1**
Protection of metallic materials against corrosion – Corrosion likelihood in soil – Part 1: General

— **EN 12501-2**
Protection of metallic materials against corrosion – Corrosion likelihood in soil – Part 2: Low alloyed and non alloyed ferrous materials

— **EN 13438**
Paints and varnishes – Powder organic coatings for galvanized or sherardised steel products for construction purposes

— **EN 14199**
Execution of special geotechnical works – Micropiles

— **EN 14490**
Execution of special geotechnical works – Soil nailing

— **EN 15773**
Industrial application of powder organic coatings to hot-dip galvanized or sherardized steel articles (duplex systems) – Specifications, recommendations and guidelines

— **ASTM A153**
Standard specification for zinc coating (hot-dip) on iron and steel hardware

— **ASTM A-775**
Standard specification for epoxy-coated steel reinforcing bars

— **ASTM A-934**
Standard specification for epoxy-coated prefabricated steel reinforcing bars

— **ASTM D4435**
Standard test method for rock bolt anchor pull test

— **DIN 21521-2**
Rock bolts for mining and tunnel support; general specifications for steel-bolts; tests, testing methods

— **ISRM**
Suggested methods for rock bolt testing

— **FHWA-CFL/TD-10-001. 2010**
Hollow bar soil nails – Pull-out test program

— **ETA-21/0869**
European Technical Assessment (ETA) as self-drilling rock and soil nail for temporary and permanent application

Designs and dimensions of system components as well as primary material specifications are included in Sandvik Ground Support's system brochures and approvals.

All dimensions, weights, quantities, and specifications are those applicable at the time of this publication and may be amended from time to time. Please contact your local representative for final confirmation of any key specifications.

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