DYWIDAG-SYSTEMS INTERNATIONAL

DYWIDAG Multistrand Stay Cable Systems

Alamillo Bridge Sevilla, Spain
28 DYNA Bond® Stay Cables
Maximum cable length: 292 m
Cable size: DB-E61

Provencher Bridge, Winnipeg, Canada
44 DYNA Grip® Stay Cables
Maximum cable length: 107 m
Cable sizes: DG-P12, DG-P14

Apollo-Bridge, Slovakia
66 DYNA Grip® Stay Cables
Maximum cable length: 37 m
Cable size: DG-P12

Ústi nad Labem Bridge, Czech. Republic
30 DYNA Bond® Stay Cables
Maximum cable length: 143 m
Cable sizes: DB-P12, DB-P19

Dubrovnik Bridge, Croatia
38 DYNA Bond® Stay Cables
Maximum cable length: 223 m
Cable sizes: DB-P27, DB-P61

Kampen Bridge, Netherlands
24 DYNA Grip® Stay Cables
Maximum cable length: 163 m
Cable sizes: DG-P37, DG-P55, DG-P91

Content

General

Cable stayed bridges are very efficient structural systems with light weight superstructures and large lever arms. The most important elements of these aesthetically pleasing and often dramatic structures are the closely spaced stay cables which transfer the loads to the foundation via the pylon. It is essential that these tensile elements are durable and easy to maintain. They are generally designed to be restressable and replaceable.

DYWIDAG has been involved in the development, construction and execution of stay cables and cable supported structures since 1970.

Based on internationally recognized guidelines for stay cables combined with our own design criteria of the world wide renowned DYWIDAG Multistrand tendons, we first developed stay cables with bars and applied them for large bridges (for example the Dame Point Bridge, Florida USA; main span 396 m).

Thereafter we were able to take advantage of our many years of experience and expertise in post-tensioning and prestressed concrete construction, particularly in the field of long span bridges.

DYWIDAG Multistrand Stay Cables were developed in the eighties to accommodate ever increasing spans and the resulting need for economical high capacity cables. Today strand cables are widely used for many types of structures. This brochure gives an overview of the DYWIDAG Multistrand Stay Cable Systems.The special use of stay cables for extradosed tendons is also included. More detailed information is available on request.

Quality Assurance

To ensure high quality and consequently the performance and durability of DYWIDAG Stay Cables, all components are subjected to quality tests according to our quality assurance system. DSI is ISO 9001 certified.

For internal quality control DSI maintains a test lab in Germany for in-house testing of geometry, material and performance.


CERTIFICATE

DYWIDAG Stay Cables

DYWIDAG Stay Cables are normally available in standard sizes up to 109 strands per anchorage. This maximum size was extended for the Maumee River Crossing project/USA, where DSI developed a cable with up to 156 strands. This cable is the largest in the world and has been proven successfully in static, dynamic and leak tightness tests.

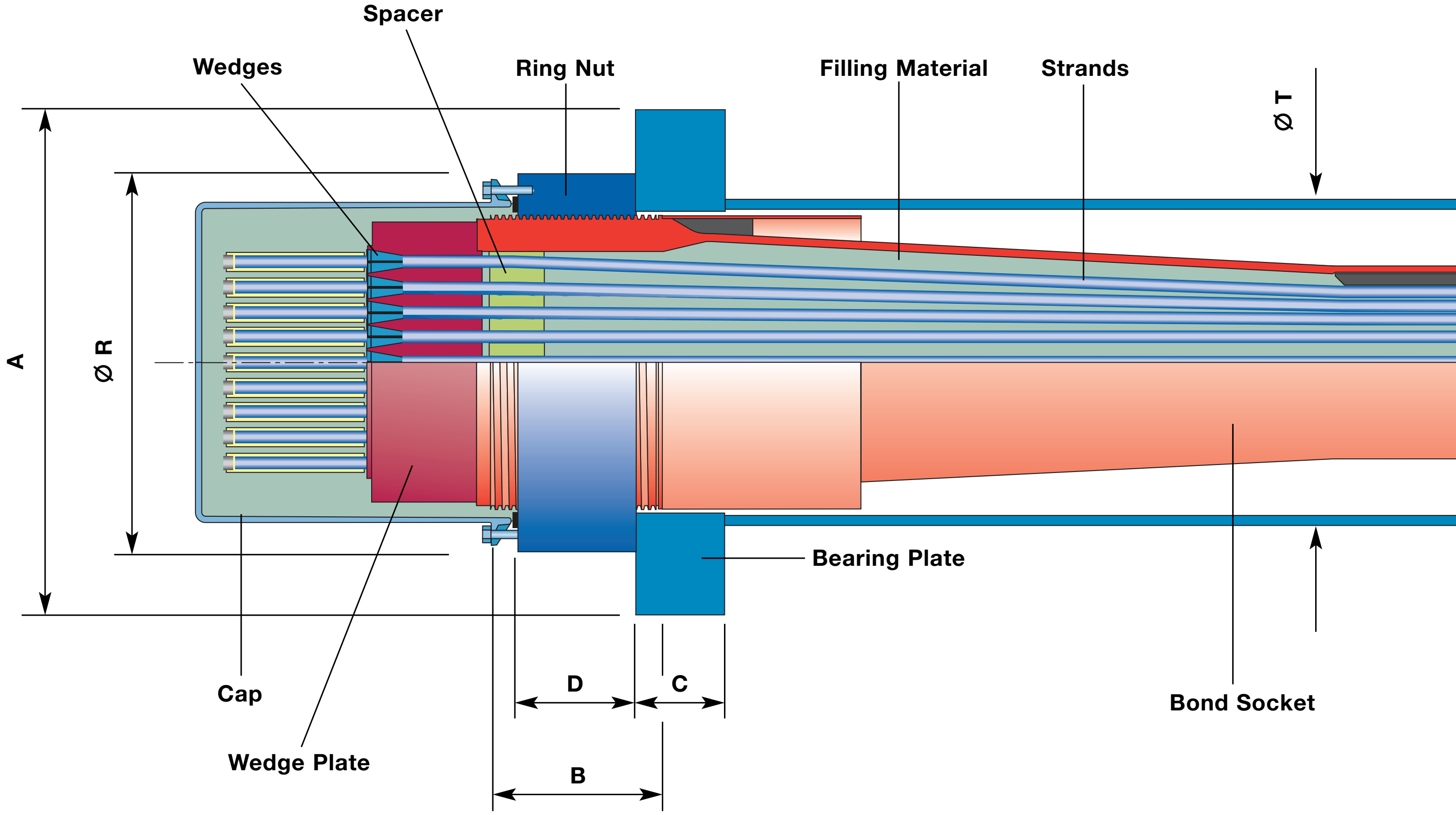
To meet demands of the market and requirements of international standards DSI provides stay cables with two basic types of anchorages:

– DYNA Bond® Anchorage
– DYNA Grip® Anchorage

The DYNA Bond® Anchorage is an anchorage with additional internal bond. It is normally grouted after application of the permanent loads of the superstructure.

The DYNA Grip® Anchorage is an anchorage without bond that permits monitoring and replacement of individual strands of a stay during its entire service life.

DYWIDAG Stay Cables are designed according to ackkowleged international requirements e.g. PTI, fib or CIP/Setra.



DYNA Bond® Anchorage

The DYNA Bond® Anchorage consists of a conical steel pipe (bond socket), supporting a wedge plate where the strands are anchored with 3-part-wedges. A ring nut is fitted on a threaded end of the bond socket and distributes the cable force through a bearing plate into the structure. During the construction phase prior to grouting the bond socket, all the applied loads are supported directly by the wedges.

After filling the bond socket with cement or epoxy grout, all additional loads (including dynamic loads from traffic, vibrations and earthquakes) are then partly resisted by the wedges and partly transmitted by bond between the strands and the grout via the bond socket directly to the bearing plate and the supporting structure (only the bond socket needs to be grouted to achieve the behaviour described above).

DYNA Bond® Anchorages have an excellent fatigue resistance because the bond action in the bond socket substantially reduces the magnitude of the dynamic loads reaching the wedge anchorage. Fatigue tests have proven that a stress range of up to 240 N/mm^2 (upper stress 0,45 GUTS) may be safely resisted for over 2 million cycles.

Additional advantages of DYNA Bond® Anchorages:

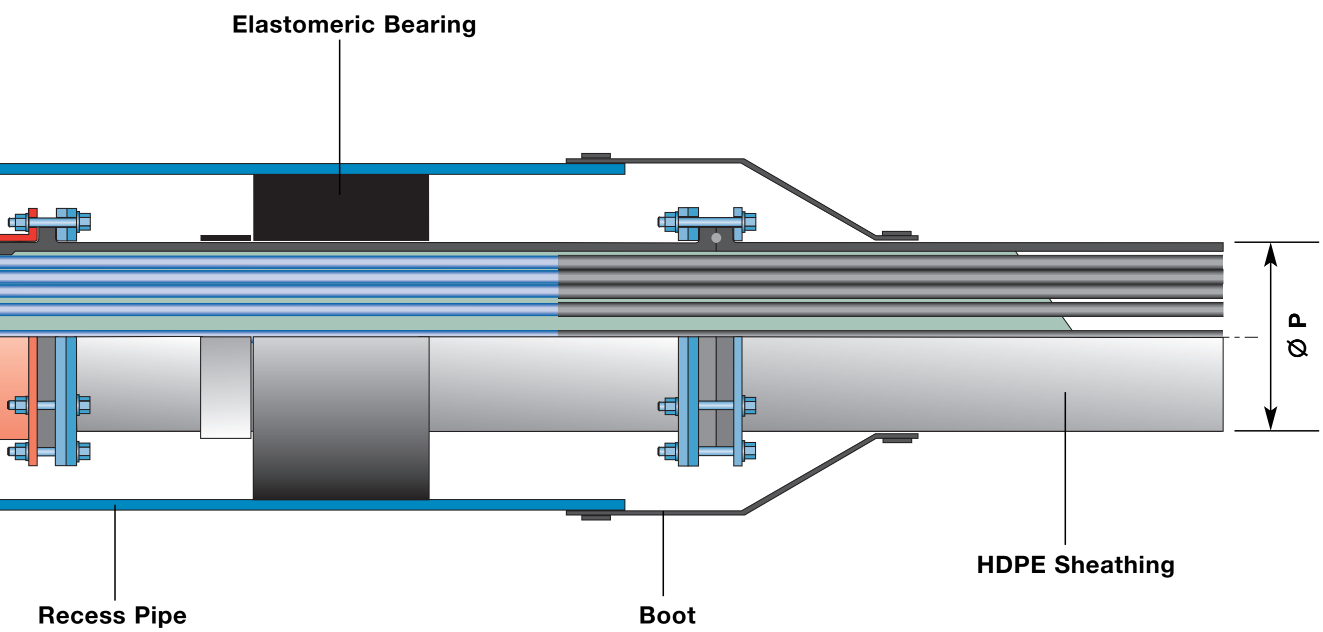
- redundant load carrying system
- reliable corrosion protection for the sensitive anchorage area because all voids in the anchorage zone are filled with a stable and robust filler
- enhanced fire resistance and protection against vandalism, impact loads and blast effects.

A further important construction detail is the use of an elastomeric bearing at a certain distance away from the anchor block. The most important requirement for the design of the bearing is to prevent the introduction of harmful bending in the anchorage area.

Because the injection of the grout extends beyond the bearing the DYNA Bond® Anchorage provides a clear statical system for the absorption of bending loads due to lateral cable movements (cable rotation).

Kap Shui Mun Bridge, Hong Kong

DYNA Bond® Anchorage

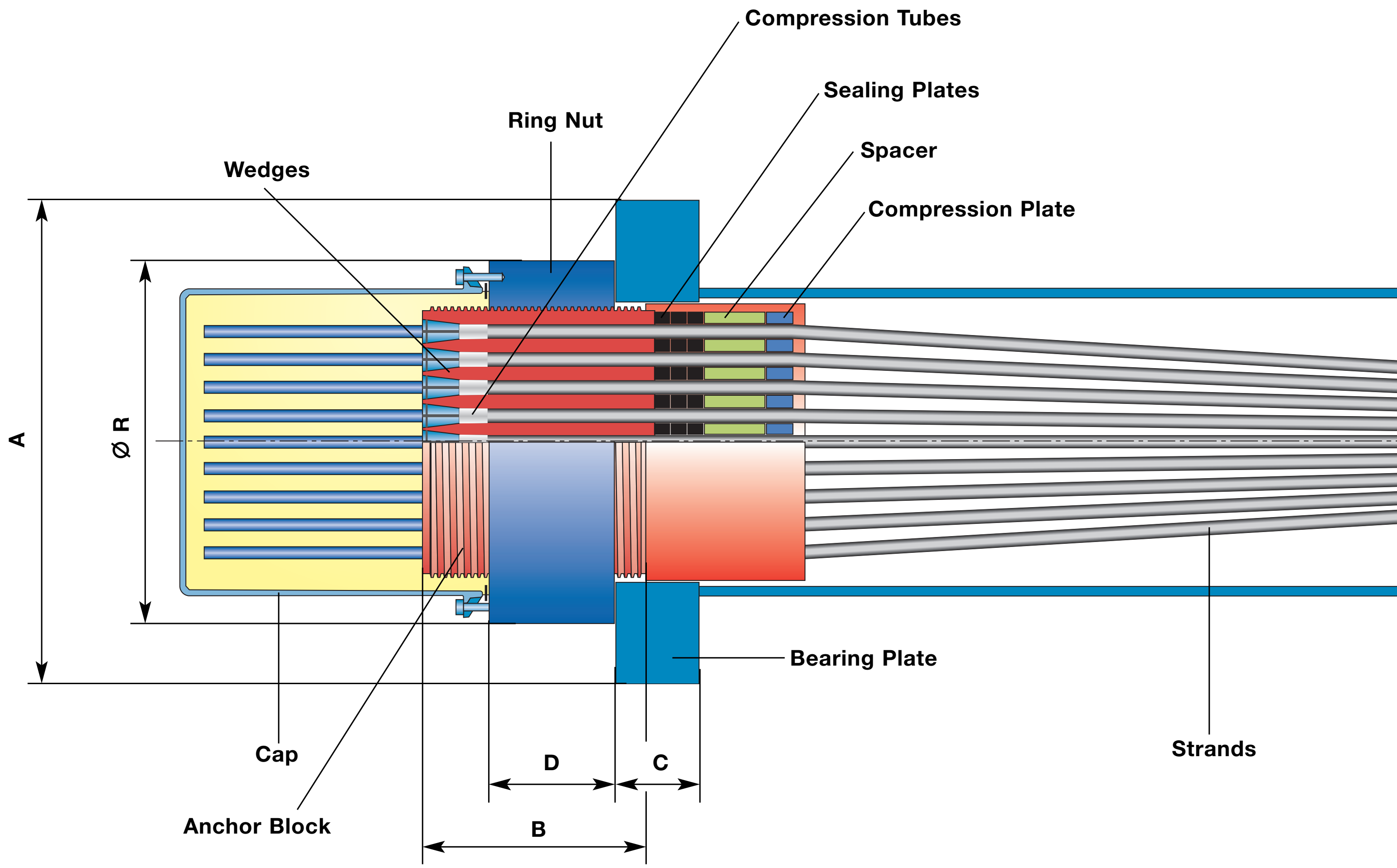


DYNA Bond® Anchorage
(forces calculated with strands 0,62" St 1620/1860)

cable type		DB-P12	DB-P19	DB-P27	DB-P37	DB-P48	DB-P61	DB-P75	DB-P91	DB-P108
No. of strands		12	19	27	37	48	61	75	91	108
Forces [kN]										
ultimate load (GUTS)		3.348	5.301	7.533	10.323	13.392	17.019	20.925	25.389	30.132
working load (0,45 x GUTS)		1.507	2.385	3.390	4.645	6.026	7.659	9.416	11.425	13.559
Dimensions [mm]										
bearing plate (for C35/45)	A	300	370	430	500	580	640	715	780	855
bearing plate	C	50	60	70	80	90	100	110	120	130
thread *	B	125	133	142	154	170	175	195	215	235
ring nut	D	90	100	110	120	135	150	170	190	210
ring nut	Ø R	244	287	326	378	434	480	536	584	636
recess pipe	Ø T	219	245	299	324	394	419	470	508	559
HDPE sheathing	Ø P	110	140	160	180	200	225	250	280	315

* standard length, to be longer on special request

Subject to modification



DYNA Grip® Anchorage

Project specifications often require that individual strands of stay cables be inspectable and, if necessary, replaceable. For these requirements DSI developed the DYNA Grip® Anchorage providing the opportunity to inspect individual strands without damaging the stay cable and to replace strands if necessary.

The DYNA Grip® Anchorage consists of an anchor block in which the strands are anchored by 3 part-wedges with high dynamic performance. A ring nut is threaded on the anchor block to transmit the cable force via the bearing plate into the structure. A steel pipe which incorporates centering and sealing provisions for the strands is welded to the anchor block.

Fatigue tests have proven a dynamic stress range of up to 200 N/mm^2 (upper stress 0,45 GUTS at 2 million load cycles). Test with 0.6° inclined anchorages according to the new fib bulletin 30 were also successfully performed.

Special features of DYNA Grip® Anchorages:

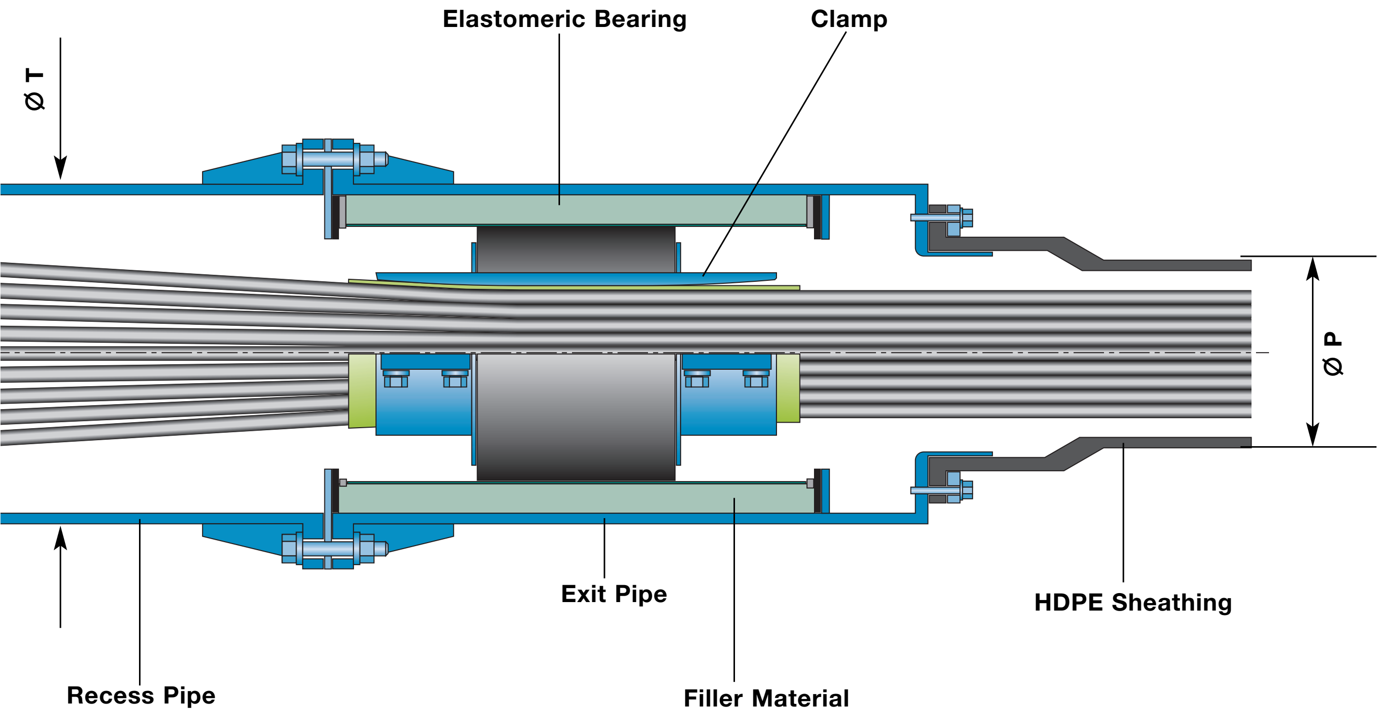
- the factory applied corrosion protection of the PE-coated strands continues directly up to the wedges. This significantly reduces the space in the anchorage which is to be filled with corrosion protection compound and improves durability.
- exact cutting to length of the strands and removal of the PE coating is not necessary. Using special equipment, the PE-coating is removed using a DSI developed, patented procedure during the first stressing. In cases where subsequent stressing actions are necessary, the remaining PE-coating is compressed by the compression tubes held by the wedges while the strand is pulled through and elongated by the jack.
- restressing and replacement of individual strands as well as of the complete cable is possible.

Similar to the DYNA Bond® Anchorage, an elastomeric bearing is installed at a certain distance away from the anchor block to reduce the bending stresses in the strands caused by cable rotation.

A clamp, installed after stressing on the strand bundle, keeps the strand in a compact hexagonal pattern and acts as a support for the elastomeric bearing. In the drawing above, a version is shown that is able to accommodate construction tolerances between the cable axis and the axis of the recess pipe.

Rosario Victoria Bridge, Argentina

DYNA Grip® Anchorage



DYNA Grip® Anchorage
(forces calculated with strands 0,62" St 1620/1860)

cable type		DG-P12	DG-P19	DG-P31	DG-P37	DG-P55	DG-P61	DG-P73	DG-P91	DG-P109*
No. of strands		12	19	31	37	55	61	73	91	109
Forces [kN]										
ultimate load (GUTS)		3.348	5.301	8.649	10.323	15.345	17.019	20.367	25.389	30.411
working load (0,45 x GUTS)		1.507	2.385	3.892	4.645	6.905	7.659	9.165	11.425	13.685
Dimensions [mm]										
bearing plate (for C35/45)	A	300	370	460	500	600	640	715	780	855
bearing plate	C	50	60	75	80	95	100	110	120	130
thread **	B	200	220	230	240	270	275	290	310	340
ring nut	D	90	110	120	130	160	165	180	200	230
ring nut	Ø R	244	287	350	378	440	480	536	600	636
recess pipe	Ø T	219	245	299	324	368	406	457	495	521
HDPE sheathing	Ø P	110	140	160	180	200	225	250	280	315

* up to 156 on special request
** standard length, to be changed on special request

Subject to modification

Strands, Wedges and Corrosion Protection

DYWIDAG Stay Cables use strands that meet the requirements of the **fib and PTI-Recommendations** for stay cables, **ASTM**, **BS** as well as other national or international standards.

Generally for both anchor types strands are used

- consisting of 7 cold-drawn galvanized wires
- diameters up to 0.62" and steel grades up to 1860 mm^2
- with low relaxation
- PE-coated and waxed.

If required, epoxy-coated strands may also be used with either cable system.

Strands are anchored with special treated 3-part wedges which are characterised by a high fatigue resistance.

Wedges for Galvanized Strands

Clevis Anchorage

For special cases DSI developed a compact clevis anchorage that is easy to install.

Clevis Anchorage

Outer Sheathing

Standard HDPE-pipes are typically used for the outer casing of the DYWIDAG Stay Cables. They serve as a protection against environmental influences and reduce the wind loads on the cable. The pipes may be supplied in a wide variety of UV-resistant colours. They can also be provided with an outer helix to suppress rain-wind induced cable vibrations.

Steel or stainless steel pipes are available on special request.

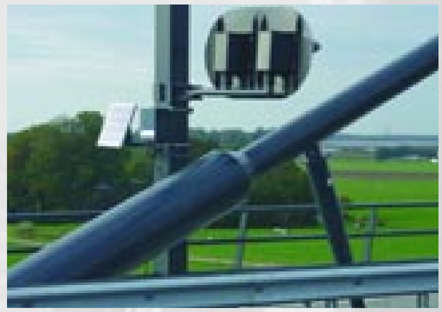
PE-Sheathing with Helix

Bearings and Dampers

Elastomeric bearings near the anchorages reduce the bending stresses in the anchorage zone and act as dampers against cable vibrations.

DYWIDAG stay cables can be equipped with devices enabling the immediate or later assembly of external dampers.

DSI will provide additional damping devices to reduce cable vibrations on request.



Installed External Damper

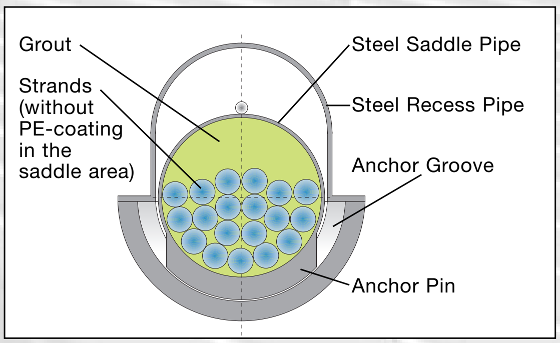
Test Installation of a Hydraulic Damper

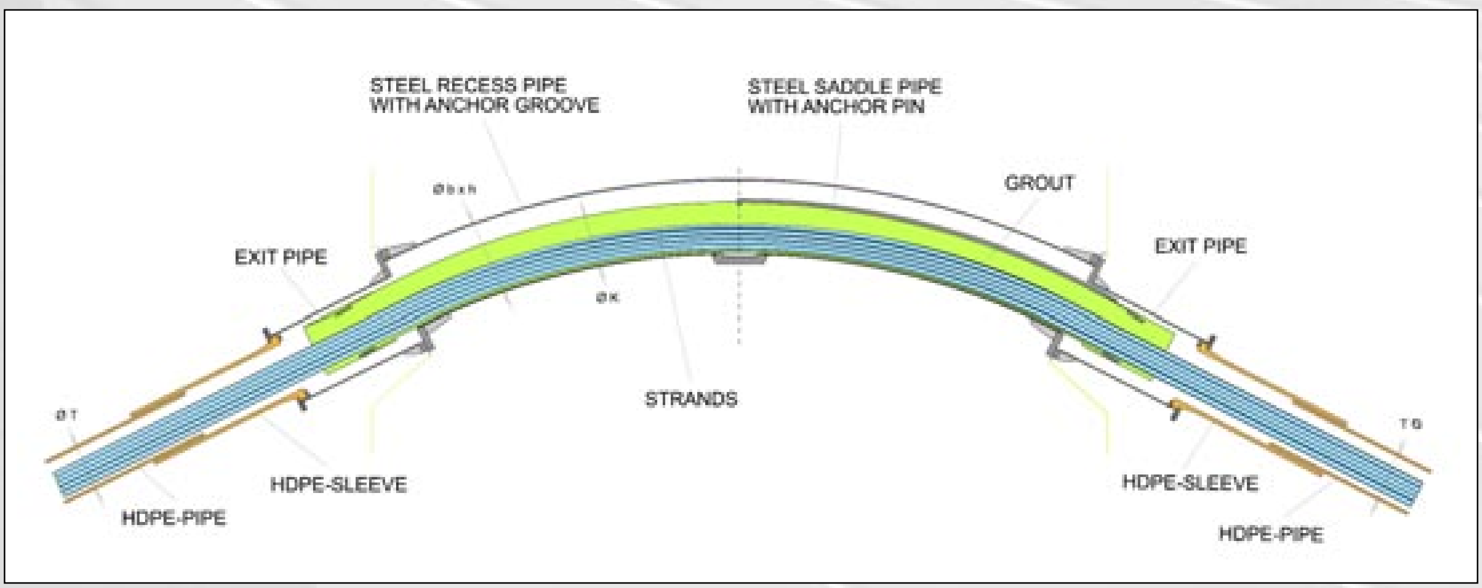
Saddle

DYWIDAG-Systems International developed a saddle, that is capable of transfering differential forces. It is replaceable due to an anchor groove - pin construction

Saddle Pipe Installation

Installed Saddle Construction





Saddle with Anchor Groove and Anchor Pin

Tests

DYWIDAG Stay Cables have been successfully tested in static and fatigue tests in compliance with **PTI** and/or **fib recommendations**. Also tests with 0.6° inclined anchorages and the leak tightness test – required by fib bulletin 30 – were successfully conducted.

Fatigue Test at the Technical University Munich

Anchorage of a Fatigue Test

Leak Tightness Test at DSI Laboratory

Installation

DSI has developed various methods to optimize and simplify the cable installation procedures depending on site specific space and time constraints.

- Prefabrication of cables on site:
  This method is preferably used for short cables. They are lifted into position with cranes.
  Because of favourable site conditions at the Alamillo cable stayed bridge in Spain 300 m long locally prefabricated cables could be installed using a winch.

- Pushing of strands into prefabricated sheathing:
  The sheathing is prefabricated on site and brought to the inclined position in the bridge. The strands are then pushed in one by one using a light pusher.

- Pulling in strands into prefabricated sheathing:
  Here also the prefabricated sheathing is brought to the inclined position. The strands are pulled in one by one using small winches.

Stressing

Depending on project requirements DSI employs two different stressing methods.

1. Stressing with multistrand jacks
This procedure can be used for cables with DYNA Bond® Anchorages.

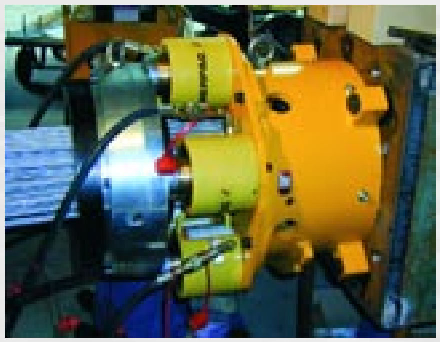
All strands in a cable are stressed simultaneously with one hydraulic jack attached to the anchorage.

Jacks up to a capacity of 15,000 kN are available.

The advantage of this method is the fast and accurate stressing operation of the cable in one step. However, it is important to provide sufficient working space at the anchorage and to be aware of the fact that special lifting devices may be needed to handle the jacks efficiently.

Multistrand Jack 15,000 kN

ConTen Jacks



Gradient Jack

2. Stressing with monojacks using the ConTen-System
This patented procedure is applicable for both DSI DYNA Bond® and DYNA Grip® stay cable systems.

All single strands are stressed immediately after being installed in the cable anchorages thus optimising the entire installation process. A special calculation method has been developed by DSI to determine the force for the first strand and the corresponding forces for the subsequent strands in order to monitor the stressing operation up to the required final cable force.

A light weight monojack is placed on a stressed strand and an identical jack is placed on the strand to be stressed next. The jacks are hydraulically linked to compare the actual pressure in both jacks during stressing. This ConTen-System makes it possible to equalize the force in all strands at the end of the stressing operation. In addition the influence of temperature and load changes in the cables and in the structure during stressing are automatically eliminated.

After completion of the structure it is possible to adjust the cable force by restressing or destressing the complete cable via the ring nut (shims are used in case of longer elongations). Special compact and light weight gradient jacks are available for adjusting the cable force and the bridge profile, if necessary.

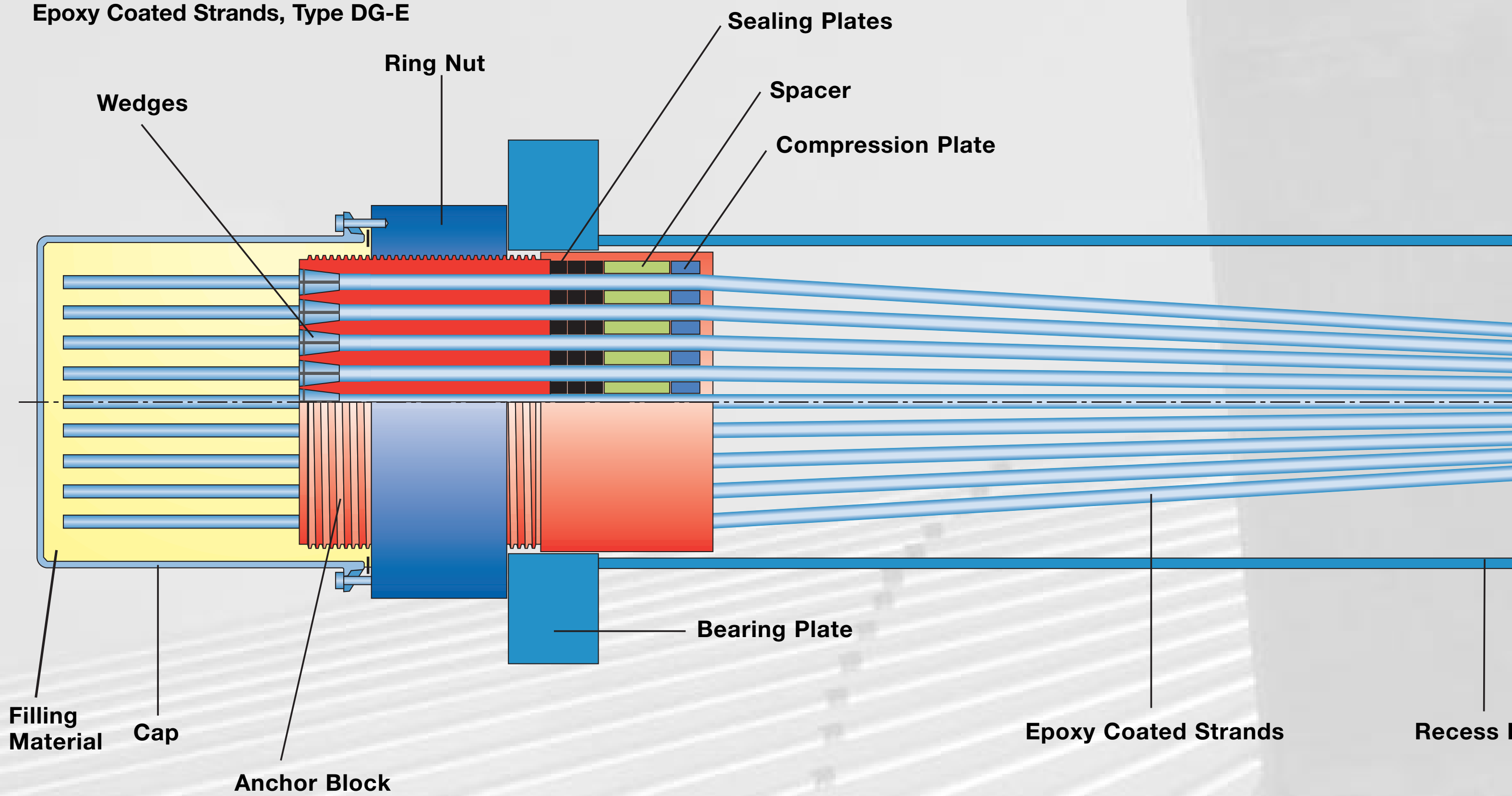
→ see table on page 14

DSI Services

- Comprehensive consulting services
- Special design and installation planning
- Component manufacture and delivery
- Installation: either turn-key using DSI staff, or project supervision and staff training
- Inspection and maintenance services

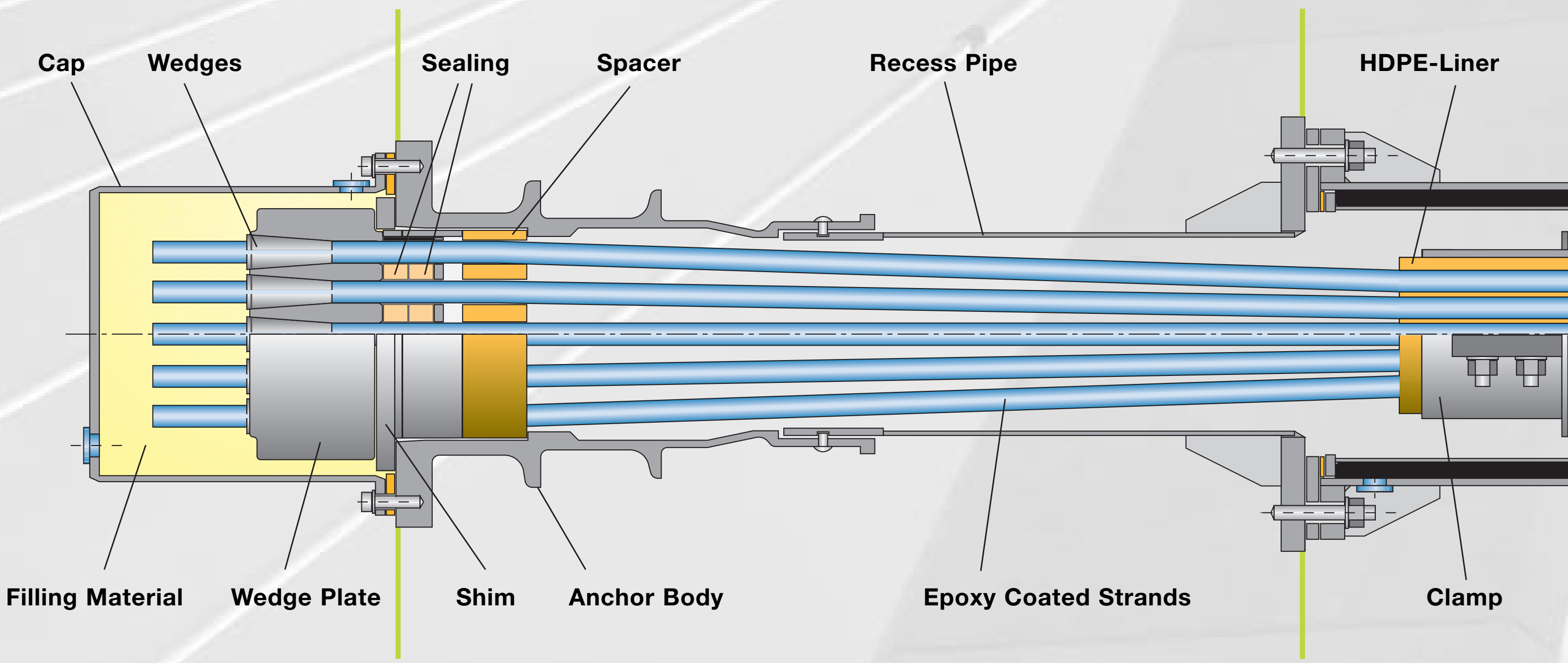
DYNA Grip® Anchorage with Epoxy Coated Strands, Type DG-E

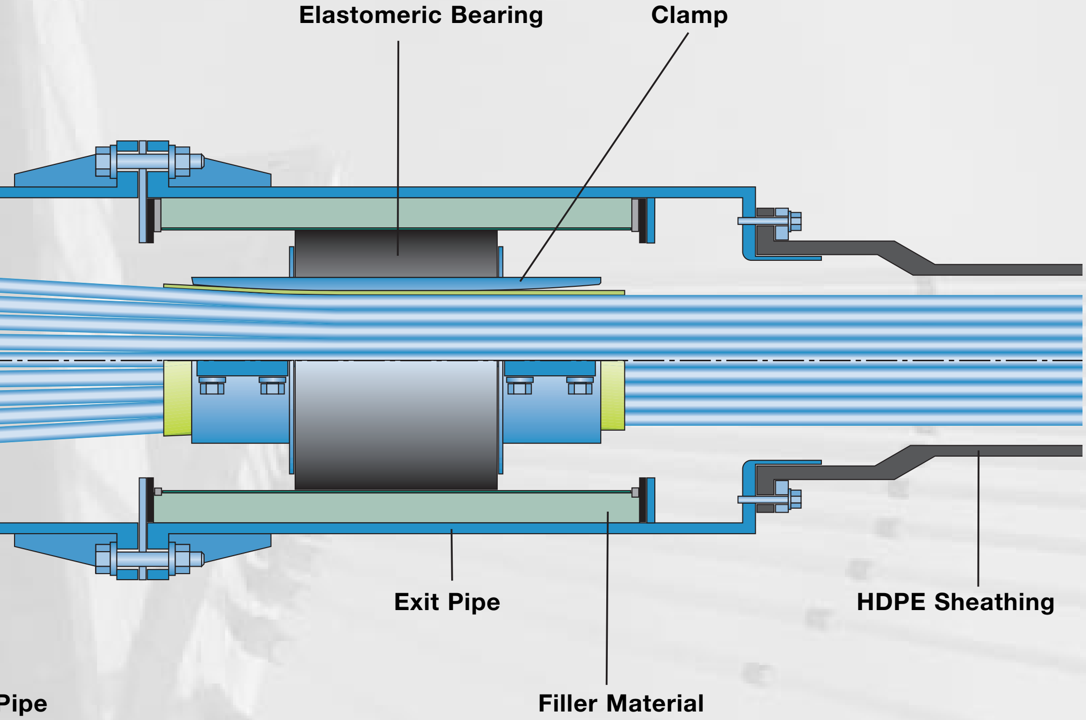
DYNA Grip® Anchorage with Epoxy Coated Strands, Type DG-E



DYWIDAG Extradosed Tendons

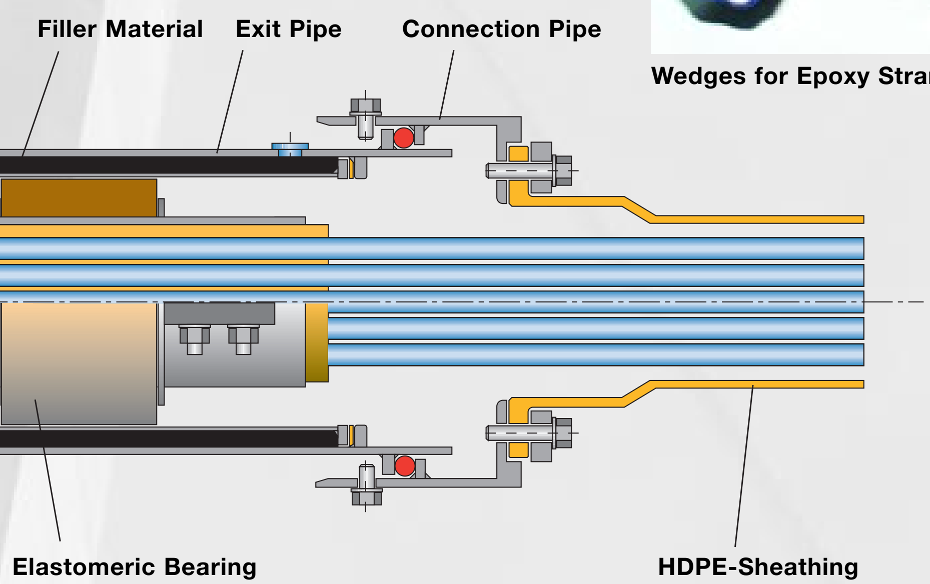
DYWIDAG Extradosed Tendon, Type XD-E





Epoxy coated strand

Wedges for Epoxy Strands



DYNA® Anchorages with Epoxy Coated Strands

Based on the DYNA Bond® and DYNA Grip® Systems, DSI can also offer stay cables using epoxy coated strands.

Epoxy Coated Strand

Epoxy coated strand is manufactured in compliance with ISO 14655:1999. The cold-drawn 7-wire strand is coated with epoxy resin in the shop. The interstices between the 7 wires are completely filled with epoxy resin thus providing an excellent and robust long-time corrosion protection. The epoxy material also reduces fretting action between the individual wires and cushions adjacent strands in deviation areas. Due to the good bond of the epoxy with the steel wires and combined with the ductile behavior of the epoxy material, the possibility of damage to the corrosion protection barrier during stressing is eliminated.

The 3-part wedges are specially designed for epoxy coated strands. The teeth penetrate through the coating so that they grip into the wires of the strand. Fatigue tests conducted on single-strand tendons have proven a dynamic stress range of up to 260 N/mm^2 (upper stress 0.45 GUTS at 2 million load cycles).

DYWIDAG Extradosed Tendons

DYWIDAG Stay Cables can also be used for extradosed tendons. In case of high-stress amplitudes, the strands are anchored with DYNA Bond® or DYNA Grip® Anchorages.
In case of low amplitudes, a special anchorage based on DYWIDAG External Tendons was developed. The picture shows a DYWIDAG Extradosed Cable Type XD-E with an adjustable elastomer bearing incorporating epoxy coated strands.

The DYWIDAG Extradosed Cables are replaceable, restressable and destressable.

A saddle construction as already described can also be used.

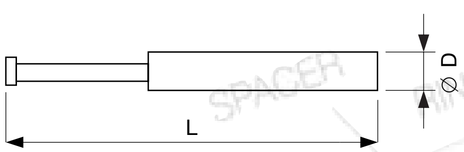
Stay Cable Jacks

Jacks	Type	Capacity kN	Cable Type	max. strand no.	B mm	C mm	D mm	E mm	L mm	Weight kg	Strand Protrusion mm
ConTen Jacks	140 kN	137	All Types	All Types	–	–	65	–	950	~ 17	1100
	180 kN	182	All Types	All Types	–	–	73	–	950	~ 19	1100
Multistrand Jacks	HOZ 3000	3054	DYNA-BOND	12	275	300	385	690	1130	~ 400	470
	HOZ 4000	4204	DYNA-BOND	19	305	366	482	755	1250	~ 600	650
	6800	6803	DYNA-BOND	27	280	395	560	185	1250	~ 1200	1150
	8600	8617	DYNA-BOND	37/61	405	646	750	840	1370	~ 2200	1400
	9750	9748	DYNA-BOND	37	335	470	680	195	1170	~ 1800	1200
	15000	15632	DYNA-BOND	61/108	510	750	980	390	1700	~ 5400	1700
Gradient Jacks	C 27	3500	DYNA-BOND	27	–	–	560 x 610	–	725	~ 400	540 *)
	C 37	4200	DYNA-BOND/GRIP	37	–	–	610 x 610	–	820	~ 520	660 *)
	C 61	6800	DYNA-BOND/GRIP	61	–	–	700 x 700	–	865	~ 700	680 *)
	C 73	8400	DYNA-GRIP	73	–	–	780 x 760	–	965	~ 820	780 *)

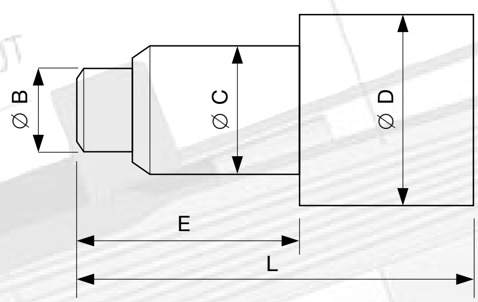
Jack dimensions without lifting devices
For working space min 2 cm around to be added

*) measured from bearing plate

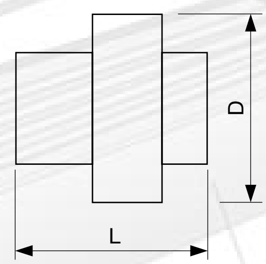
ConTen Jack



Multistrand Jacks



Gradient Jacks



Apollo Steel Arch Bridge, Bratislava, Slovakia

References

Name / Project	Service	Country	Year	Stay Details: Number of Pylons	Stay Details: Number of Stays	Type	Bridge Geometry: Tonnage [t]	Bridge Geometry: width [m]	Bridge Geometry: Main Opening [m]
2. Main Bridge Frankfurt	rail/road	Germany	1972	1	104	multi bar	290	31,0	94+148+26
Penang Bridge	road	Malaysia	1984	2	148	multi bar	618	29,7	108+225+108
Muna Water Reservoir	reservoir	Saudi Arabia	1985	44	616	DYNA Bond®	495		60+220+60
Shin Ayabe Bridge	road	Japan	1986	1	20	multi bar	95	10,8	110
Dame Point Bridge	road	USA	1987	2	288	multi bar	1800	32,3	198+396+198
Quincy Bridge	road	USA	1987	2	56	DYNA Bond®	234	17,7	134+274+134
Olympic Grand Bridge	road	South Korea	1988	1	48	DYNA Bond®	330	30,0	150+150
Alamillo Bridge, Sevilla	road	Spain	1991	1	28	DYNA Bond®	330	32,0	200
Paterna Bridge	road	Spain	1991	1	10	DYNA Bond®	26	17,0	64+34
Clark Bridge, Alton	road	USA	1993	2	40	DYNA Bond®	351	31,4	92+231+92
Odawara Blueway Bridge	road	Japan	1994	2	64	DYNA Bond®	60	13,0	74+122+74
Salpasilta	pedestrian	Finland	1994	1	12	mono bar	3,4	4,5	20+40
Lechsteg Bridge	pedestrian	Austria	1995	1	14	mono bar	3,2	4,3	32+24
Kap Shui Mun Bridge	rail/road	Hong Kong	1995	2	176	DYNA Bond®	2500	35,2	430+4x80+70
Usti nad Labem Bridge	road	Czech Republic	1997	1	30	DYNA Bond®	35	24,0	132
Sidney Lanier Bridge	road	USA	1998	2	176	DYNA Bond®	875	24,2	190+381+190
Dubrovnik Bridge	road	Croatia	2000	1	38	DYNA Bond®	310	14,0	87+304+90
Rosario Victoria Bridge	road	Argentina	2000	2	128	DYNA Grip®	770	22,8	120+350+120
Lipon Bridge	road	Finland	2000	1	13	DYNA Bond®	40	12,5	74+25
Blautal Bridge	road	Germany	2001	1	8	DYNA Bond®	8	12,0	41+29
Zevenaar Bridge	road	Netherlands	2001	4	16	DYNA Grip®	18	15,5	15+50+15
Fitchburg Bridge	road	USA	2002	2	52	DYNA Bond®	52	13,6	51+109+36

References

Name / Project	Service	Country	Year	Stay Details			Bridge Geometry		
				Number of Pylons	Number of Stays	Type	Tonnage [t]	width [m]	Main Opening [m]
Goorana Reservoir, Mecca	reservoir	Saudi Arabia	2002	10	680	mono bar	200		40+40
Nelson Mandela Bridge	road	South Africa	2002	2	52	DYNA Grip®	104	14,2	42+176+66
Kampen Bridge	road	Netherlands	2002	1	24	DYNA Grip®	187	20,0	91+150
6th Street Bridges	road	USA	2002	2	48	DYNA Grip®	205	17,5	2 x (38+60)
Maumee Bridge	road	USA	2003	1	40	DYNA Grip®	914	38,7	187+187
Lane Avenue Bridge	road	USA	2003	1	20	DYNA Grip®	19	34,2	56,5+56,5
Provencher Bridge	pedestrian	Canada	2003	1	44	DYNA Grip®	45	7	82,6+109,6
Apollo Arch Bridge	road	Slowakia	2004	2	66	DYNA Grip®	30	32	231
Ponte de Machio	road	Madeira	2004	2	8	DYNY Grip®	2	10,2	17+36+19
40th Street Arch	pedestrian	USA	2004	2	36	mono bar		6	83
44th Street Arch	pedestrian	USA	2004	2	34	mono bar		6	79
Domovinski Most	road	Croatia	2005	2	64	DYNA Bond®	152	34	72+120+72
Freddie Mac Bridge	pedestrian	USA	2005	2	6	DYNA Grip®	2,3	3,9	43,9
La Plata	road	Puerto Rico	2005	2	48	DYNA Bond®	153	29,2	80+160+80
Marsupial	pedestrian	USA	2005	6	24	mono bar		3	3x24+30+24
Ziegelgraben Bridge	road	Germany	2005	2	32	DYNA Grip®	150	16	198+126
Prospect Verona Bridge	road	USA	2005	2	40	DYNA Grip®	640	17,5	146+354+146
Pomeroy Mason	road	USA	2005	2	48	DYNA Grip®	227	23,3	74+206+74
Nymburk Bridge	road	Czech Republic	2005	2	24	DYNA Grip®	60	16,2	41+132+41
Pont de Volonne	road	France	2006	2	22	DYNA Grip®	26	11	32+102+32
Wesel Bridge	road	Germany	2006	1	72	DYNA Grip®	700	29,2	335

Addresses

DSI Holding GmbH

Dywidagstrasse 1
85609 Aschheim
Germany
Phone +49-89-30 90 50-200
Fax +49-89-30 90 50-252
E-mail: info@dywidag-systems.com
www.dywidag-systems.com

RHQ Americas

DYWIDAG-SYSTEMS
INTERNATIONAL USA INC.
320 Marmon Drive
Bolingbrook, IL 60440
USA
Phone +1-630-739 11 00
Fax +1-630-972 96 04
E-mail: dsiamerica@dsiamerica.com
www.dsiamerica.com

RHQ Europe

DYWIDAG-SYSTEMS
INTERNATIONAL GMBH
Siemensstrasse 8
85716 Unterschleissheim
Germany
Phone +49-89-30 90 50-100
Fax +49-89-30 90 50-120
E-mail: dsihv@dywidag-systems.com
www.dywidag-systems.com

RHQ Underground

DYWIDAG-SYSTEMS
INTERNATIONAL PTY. LTD.
P.O. Box 370
Charlestown NSW 2290, Australia
25 Pacific Highway
Bennetts Green NSW 2290
Phone +61-2-49 48 90 99
Fax +61-2-49 48 40 87
E-mail: dsi@dywidag.com.au
www.dsiminingproducts.com

Europe

Austria
DYWIDAG-SYSTEMS
INTERNATIONAL GMBH
Christophorusstrasse 12
5061 Elsbethen/Salzburg, Austria
Phone +43-662-62 57 97
Fax +43-662-62 86 72
E-mail: dsi-a@dywidag.co.at
www.dywidag-systems.at

Belgium and Luxembourg
DYWIDAG-SYSTEMS
INTERNATIONAL N.V.
Industrieweg 25
3190 Boortmeerbeek, Belgium
Phone +32-16-60 77 60
Fax +32-16-60 77 66
E-mail: info@dywidag.be

Croatia, Bosnia and Herzegovina
PRESS-KON
Obala Hrvatskog
narodnog preporoda 6
21000 Split, Croatia
Phone +385-21-34 27 66
Fax +385-21-3425 95

Czech Republic
SM 7, A.S.
Modřanská 43
14700 Praha 4, Czech Republic
Phone +420-2-44 46 15 40
Fax +420-2-44 46 07 52
E-mail: chvala@sm7-dsi.cz

Denmark
AAGE CHRISTENSEN A/S
Skelmosevej 10
2500 Valby, Denmark
Phone +45-36-44 24 44
Fax +45-36-44 20 24
E-mail: dsi@aagechristensen.dk

Estonia
SAGA Grupp
Peterburi tee 90
11415 Tallinn, Estonia
Phone +372 601 29 34
Fax +372 601 29 35
E-mail: erki.saar@saga.ee

Finland
TENSICON OY
Rattitie 17
007700 Helsinki 77, Finland
Phone +358-9-35 05 99 0
Fax +358-9-35 05 99 10

France
DYWIDAG-SYSTEMS
INTERNATIONAL GMBH

Succursale France
8. rue du Grand Pré
95640 Marines, France
Phone +33-1-30 39 42 42
Fax +33-1-30 39 62 72
E-mail: dsi.france@dywidag.fr
www.dywidag.fr

Agence de Lyon
14, rue de la Prairie
69100 Villeurbanne, France
Phone +33-4-78 79 27 82
Fax +33-4-78 79 01 56
E-mail: dsi.france@dywidag.fr

Agence de Marseille
55, rue Louis Armand - BP 266
13797 Aix-en-Provence Cedex 3,
France
Phone +33-4-42 24 56 46
Fax +33-4-42 90 00 58
E-mail: dsi.france@dywidag.fr

Germany
SUSPA-DSI GmbH
Max-Planck-Ring 1
40764 Langenfeld, Germany
Phone +49-2173-79 02 0
Fax +49-2173-79 02 20
E-mail: info@suspa-dsi.de
www.suspa-dsi.de

SUSPA-DSI GmbH
Germanenstrasse 8
86343 Koenigsbrunn, Germany
Phone +49-8231-96 07 0
Fax +49-8231-96 07 40
E-mail: info@suspa-dsi.de

SUSPA-DSI GmbH
Schuetzenstrasse 20
14641 Nauen, Germany
Phone +49-3321-44 18 0
Fax +49-3321-44 18 18
E-mail: info@suspa-dsi.de

DYWIDAG-SYSTEMS
INTERNATIONAL GMBH
Business Unit Form Ties Systems
Schallbruch 53-55
42781 Haan, Germany
Phone +49-2129-93 22 0
Fax +49-2129-93 22 10
E-mail: dsihaan@dywidag-systems.com

United Kingdom
DYWIDAG-SYSTEMS
INTERNATIONAL LTD.
Northfield Road
Southam, Warwickshire
CV47 OFG, England
Phone +44-1926-81 39 80
Fax +44-1926-81 38 17
E-mail: sales@dywidag.co.uk
www.dywidag.co.uk

Greece
For Geotechnical Systems
HELLENPLAN
18, Filolaou Street
Athens 11633, Greece
Phone +30-210-752 07 53
Fax +30-210-751 210 68
E-mail: vtsio@tee.gr

For Post-Tensioning Systems
Kostantinos Zervas
34th Sintagmatos Pezikon 5
Pireas TK 18532 Athens
Greece
Phone +30-210-417 62 76
Fax +30-210-412 21 23
E-mail: kzervas@tee.gr

Italy
DYWIT S·P·A
Via Albricci, 5
20122 Milano, Italy
Phone +39-02-72 00 06 77
Fax +39-02-86 93 93 5
E-mail: dywit@tin.it

Addresses

Netherlands
DYWIDAG-SYSTEMS
INTERNATIONAL B.V
Veilingweg 2
5301 KM Zaltbommel
Netherlands
Phone +31-418-57 89 22
Fax +31-418-51 30 12
E-mail: email@dsi-nl.nl
www.dsi-nl.nl

Norway
DYWIDAG-SYSTEMS
INTERNATIONAL A/S
P.O. Box 113
1483 Skytta, Norway
Phone +47-67-06 15 60
Fax +47-67-06 15 59
E-mail: manager@dsi-dywidag.no

Portugal
DYWIDAG-SYSTEMS
INTERNATIONAL GMBH (Sucursal)
Alameda dos Oceanos, lote 3.15.01 D
Escritório 7
1990 - 197 Lisboa, Portugal
Phone +351-21-892 28 90
Fax +351-21-892 28 99
E-mail: dsi.lisboa@dywidag.pt

Russia
Promstroikontrakt
h. 10, 3-rd Setunsky Proezd, Moscow,
Russia, 119136
Phone +7 095 247-90-91
Fax +7 095 789-34-12
E-mail: psk@psk-holding.ru
www.psk-holding.ru

Sweden
SpännProjekt
Tallhammarsvägen 11
18633 Vallentuna, Sweden
Phone +46-8-51 17 51 00
Fax +46-8-51 17 17 00
E-mail: spannprojekt
@beta.telenordia.se

Switzerland
SpannStahl AG
Industriegebiet
Waesseristrasse 29
8340 Hinwil/ZH, Switzerland
Phone +41-1-938 97 97
Fax +41-1-938 97 90
E-mail: info@spannstahl.ch
www.spannstahl.ch

Spain
DYWIDAG SISTEMAS
CONSTRUCTIVOS, S.A.
Avenida de la Industria, 4
Pol. Ind. La Cantuena
28947 Fuenlabrada (MADRID), Spain
Phone +34-91-642 20 72
Fax +34-91-642 27 10
E-mail: dywidag
@dywidag-sistemas.com
www.dywidag-sistemas.com

Far and Middle East

Iran
PADSI CO.
31, Varshow St.
Nejatollahi (Villa) Ave.
Tehran - 15986 Iran
Phone +98-21-890 17 99
Fax +98-21-890 53 78

Lebanon
SOPREL Liban SAL
Liban Cable Street
Halate, Lebanon
Phone +961 9 44 88 60
Fax +961 9 44 71 71
E-mail: contact@soprel-liban.com

Saudi Arabia
DYWIDAG
SAUDI ARABIA CO., LTD
P.O. Box 1261
Jubail 31951,
Kingdom of Saudi Arabia
Phone +966-3-341-63 06 / 341 63 07
Fax +966-3-341-63 02
E-mail: dsa@dywidag.com.sa

Turkey
DIVIGER Yapi Teknoloji A.S.
Yildizposta Cd. Ayyildiz Sitesi 30/15
34353 Istanbul-Gayrettepe, Turkey
Phone +90-212-234 56 12
Fax +90-212-347 39 49
E-mail: diviger@diviger.com

United Arab Emirates, Qatar, Oman
MBM
23rd Street (Villa No. 28/3)
Abu Dhabi - U.A.E.
Phone +971-2-448 32 32
Fax +971-2-448 32 36
E-mail: mbm@mbmauh.ae

North and Central America

USA
DYWIDAG-SYSTEMS
INTERNATIONAL USA INC.

Headquarter
320 Marmon Drive
Bolingbrook, IL 60440, USA
Phone +1-630-739 11 00
Fax +1-630-972 96 04
E-mail: dsiamerica@dsiamerica.com
www.dsiamerica.com

Business Unit
Post-Tensioning & Reinforcement
320 Marmon Drive
Bolingbrook, IL 60440, USA
Phone +1-630-739 11 00
Fax +1-630-972 96 04
E-mail: dsiamerica@dsiamerica.com

525 Wanaque Avenue
Pompton Lakes, NJ 07442, USA
Phone +1-973-831-6560
Fax +1-973-831-6503
E-mail: dsiamerica@dsiamerica.com

1801 N. Peyco Drive
Arlington, TX 76001-6704, USA
Phone +1-817-465 33 33
Fax +1-817-465 36 96
E-mail: dsiamerica@dsiamerica.com

4732 Stone Drive, Suite B
Tucker, GA 30084, USA
Phone +1-770-491 37 90
Fax +1-770-938 12 19
E-mail: dsiamerica@dsiamerica.com

2154 South Street
Long Beach, CA 90805, USA
Phone +1-562-531 61 61
Fax +1-562-531 26 67
E-mail: dsiamerica@dsiamerica.com

Business Unit
Geotechnical Systems
DSI-Lang Geotech LLC
1263 Newark Road
Toughkenamon, PA 19374, USA
Phone +1-610-268-2221
Fax +1-610268-3053
E-mail: support@dsi-lang.com

1305 S. Central Ave
Unit H
Kent, WA 98032, USA
Phone +1-253-859-9995
Fax +1-253-859-9119
E-mail : support@dsi-lang.com

320 Marmon Drive
Bolingbrook, IL 60440, USA
Phone +1-630-739 11 00
Fax +1-630-972 96 04
E-mail: support@dsi-lang.com

525 Wanaque Avenue
Pompton Lakes, NJ 07442, USA
Phone +1-973-831-6560
Fax +1-973-831-6503
E-mail: dsiamerica@dsiamerica.com

1801 N. Peyco Drive
Arlington, TX 76001-6704, USA
Phone +1-817-465 33 33
Fax +1-817-465 36 96
E-mail: support@dsi-lang.com

4732 Stone Drive, Suite B
Tucker, GA 30084, USA
Phone +1-770-491 37 90
Fax +1-770-938 12 19
E-mail: support@dsi-lang.com

2154 South Street
Long Beach, CA 90805, USA
Phone +1-562-531 61 61
Fax +1-562-531 3266
E-mail: support@dsi-lang.com

Business Unit
Monostrand
2154 South Street
Long Beach, CA 90805, USA
Phone +1-562-531 61 61
Fax +1-562-531 2667
E-mail: dsiamerica@dsiamerica.com

320 Marmon Drive
Bolingbrook, IL 60440, USA
Phone +1-630-739 11 00
Fax +1-630-972 96 04
E-mail: dsiamerica@dsiamerica.com

525 Wanaque Avenue
Pompton Lakes, NJ 07442, USA
Phone +1-973-831-6560
Fax +1-973-831-6503
E-mail: dsiamerica@dsiamerica.com

1801 N. Peyco Drive
Arlington, TX 76001-6704, USA
Phone +1-817-465 33 33
Fax +1-817-465 36 96
E-mail: dsiamerica@dsiamerica.com

10060 N.W. 53rd Street
Sunrise, Florida 33351
Phone +1-954-318-1106
Fax +1-954-318-1107
E-mail: dsiamerica@dsiamerica.com

Addresses

Business Unit
Form Tie Systems
2154 South Street
Long Beach, CA 90805, USA
Phone +1-562-531 61 61
Fax +1-562-531 2667
E-mail: dsiamerica@dsiamerica.com

Canada
DYWIDAG-SYSTEMS
INTERNATIONAL
CANADA LTD.

Eastern Division
37 Cardico Drive
Gormley, Ontario
L0H 1G0, Canada
Phone +1-905-888-8988
Fax +1-905-888-8987
E-mail: dsiamerica@dsiamerica.com

Western Division
Suite 103
19433 96th Avenue
Surrey, BC V4N 4C4, Canada
Phone +1-604-888-88 18
Fax +1-604-888-50 08
E-mail: dsiamerica@dsiamerica.com

Central America

Costa Rica
SUPERBA S.A.
Pozuelo 100M Norte y 25 Oeste
La Uruca, San José, Costa Rica
Phone +50-6-255 10 44
Fax +50-6-255 11 10
E-mail: superba@sol.racsa.co.cr

Guatemala
Preforzados y Construcciones S.A.
5 Av.6-39
zona 14 Las Plazas
Guatemala 01014
Phone + 50-2-631-4882/4
Fax + 50-2-368-3531
E-Mail: precon@terra.com.gt

Honduras
Lazarus & Lazarus
200 Mts. Al Este de Posta de Peaie
Boulevard del Sur
Chamalecon Cortes
Phone + 50-4565-8882
Fax + 50-4565-8624
E-Mail: elazarus@latarus.hn

DSI Mexico, S.A. DE C.V.
Calle Tecuitapan #6
Col. Las Palmas CP 62050
Cuernavaca, Morelos, Mexico
Industria del Vestido # 2153
Zapopan, Jalisco - Mexico 45132
Phone +52-7773-12 64 96
Fax +52-7773-14 14 79
E-mail: dsimexico@infosel.net.mx

South America

Argentina-Uruguay-Paraguay
Compañía Sudamericana de
Postensado
CSP-DSI Argentina
Av. Leandro N. Alem 661 7° Piso Of.
17
1001 Buenos Aires
Argentina
Phone +54-11-43 12-44 34 / 35
Fax +54-11-43 12-11 43
E-mail: info@csp-dsi.com

Brazil
PROTENDIDOS DYWIDAG LTDA.
Rua Marquês de Itu, 58 - 15° Andar
CEP 01223-905 - São Paulo - SP
Brazil
Phone +55 11 3231-3799
Fax +55 11 3231-1276
E-mail: info@dywidag.com.br
www.dywidag.com.br

Chile
Compañía Sudamericana de
Postensado
CSP-DSI Chile
Av. Apoquindo 3076 Piso 6
Santiago de Chile, Chile
Phone +56-2-952 0679
Fax +56-2-952 0681
E-mail: info@csp-dsi.cl

Sr.Miguel Mandry
E.Marquina 3937 of.608
Vitacura
Santiago de Chile, Chile
Phone +56-2-2074585
Fax +56-45-718-336
E-mail: migmandry@terra.cl

Colombia
TENSAR LTDA.
Transversal 70-B No. 4-36
Santa Fé de Bogotá, Colombia
Phone +57-1-262 66 85
Fax +57-1-261 28 82
E-mail: tensarl1@latino.net.co

Peru
SAMAYCA INGENIEROS S.A.C.
Av. A. Benavides 245 Of.604-605
Lima, Perú
Phone +51-1-446 33 56
Fax +51-1-445 66 28
E-mail: samayca@terra.com.pe

Venezuela
POSTENSADO V.N. INDUSTRIAL DE
VENEZUELA S.A. (PIV)
Quinta IMOLA
6ta. transv., entre 2da y 3ra AV.
Urb. Los Palos Grandes
Caracas, Venezuela
Phone +58-212-261-8516
Fax +58-212-261-2854
E-mail: postensado@cantv.net

Africa

Egypt
MISR DYWIDAG
20 Haroun Street
Dokki-Giza
Cairo, Egypt
Phone +20-2-748 28 27
Fax +20-2-748 62 53
E-mail: mail@misrdywidag.com

Asia

China
DYWIDAG-SYSTEMS
INTERNATIONAL
FAR EAST LTD.
Room 2306
CC Wu Building
302-308 Hennessy Road
Wanchai, Hong Kong
Phone +852-2833-91 70
Fax +852-2834-55 21
E-mail: dsihk@dsife.com.hk

Indonesia
PT DELTA SYSTECH INDONESIA
Wisma Ritra 2nd Floor
Jl. Wr. Buncit Raya No.6
Jakarta - 12740
Indonesia
Phone +62-21-797 02 89
Fax +62-21-797 08 25
E-mail: yunaldi@dsi-indonesia.co.id

Japan
SUMITOMO ELECTRIC
INDUSTRIES LTD.
Special Steel Wire Division
3-12 Motoakasaka
1-chome Minato-ku
Tokyo, 107 Japan
Phone +81-3-34 23 51 31
Fax +81-3-34 23 50 01
E-mail: katsuda-hirokazu@sei.co.jp

Korea
DYWIDAG-SYSTEMS
KOREA CO.LTD.
5th Floor, Spring Morning B/D
249-2 Yangjae-dong Seocho-ku
Seoul 137-130 Korea
Phone +82-2-34 72 01 41
Fax +82-2-34 72 01 45
E-mail: dywidag@chollian.net

Singapore
UTRACO STRUCTURAL
SYSTEMS PTE LTD
7E Pioneer Sector 1
Singapore 628446
Phone +65-64153078
Fax +65-68631928
E-mail: utracoss@utracoss.com
www.utracoss.com

Taiwan
DYWITECH Co., Ltd.
13th Fl.-3, No. 163, Sec. 1, Keelung
Road
Taipei 110
Taiwan, R.O.C.
Phone +886-2-27 48 10 76
Fax +886-2-27 47 05 76
E-mail: dsitaiwan@dywidag-systems.com.tw

Thailand
D-Tech Postten Co., Ltd.
1350/136-137
10/F, Thairon Tower Building
Pattanakarn Road
Suan Luang District
Suan Luang
Bangkok 10250
Thailand
Phone +66-02-719-51 67
Fax +66-02-719-53 91
E-mail: kritpsu@yahoo.com

RHQ Underground

Australia
DYWIDAG-SYSTEMS
INTERNATIONAL PTY. LTD.

Eastern Australia
25 Pacific Highway
Bennetts Green NSW 2290
Australia
Phone +61-2-49 48 90 99
Fax +61-2-49 48 43 15
E-mail: dsi@dywidag.com.au
www.dsiminingproducts.com

Western Australia
170 Railway Parade
Bassendean WA 6054
Australia
Phone +61-8-94 49 83 33
Fax +61-8-94 49 83 25
E-mail: dsi@dywidag.com.au

Mount Isa
199 Camooweal Street
Mt Isa QLD 4825
Australia
Phone +61-7-47 43 42 44
Fax +61-7-47 43 27 11
E-mail: dsi@dywidag.com.au

Emerald
3 McKenzie Street
Emerald QLD 4720
Australia
Phone +61-7-49 82 06 02
Fax +61-7-49 87 42 58
E-mail: dsi@dywidag.com.au

Kalgoorlie
Lot 15 Cunningham Road
Kalgoorlie WA 6430
Australia
Phone +61-8-90 91 19 93
Fax +61-8-90 91 41 72
E-mail: dsi@dywidag.com.au

South Africa
DYWIDAG-SYSTEMS
INTERNATIONAL PTY. LTD
P.O. Box 60 59
Homestead 1412
30 North Reef Road
Elandsfontein
Johannesburg
Gauteng South Africa
Phone +27-11 878 68 00
Fax +27-11 878 68 11
E-mail: dsi@dywidag.co.za

DSI-Mandirk
P.O. Box 60 59
Homestead 1412
30 North Reef Road
Elandsfontein
Johannesburg
Gauteng South Africa
Phone +27-11 878 68 00
Fax +27-11 878 68 11
E-mail: dsi@dywidag.co.za

America
DSI-Thiessen Mining Division
1638 Alberta Avenue
Saskatoon, SK S7K 1R6
Phone +1-306-244-6244
Fax +1-306-931-3481
E-mail: dsiamerica@dsiamerica.com

DSI-Thiessen Mining Division
5492 – 275th Street
Langley, BC V4W 3X7
Phone +1-604-857-1500
Fax +1-604-857-1580
E-mail: dsiamerica@dsiamerica.com

DSI Ground Support
560 Notre Dame Avenue
Sudbury, ON P3C 5L2
Phone +1-705-674-5844
Fax +1-705-674-5867
E-mail: dsiamerica@dsiamerica.com

DSI Ground Control
1150 Kelly Lake Road
Sudbury, ON P3E 5P4, Canada
Phone +1-705-673-3020
Fax +1-705-673-5946
E-mail: dsiamerica@dsiamerica.com

DSI-Stewart
154, 14th Ave.
Rouyn – Noranda, PQ J9X 2J5
Canada
Phone +1-819-762-0901
Fax +1-819-797-1367
E-mail: dsiamerica@dsiamerica.com

DSI Ground Support
3900 West 700 South
Salt Lake City, UT 84104, USA
Phone +1-801-973-7169
Fax +1-801-973-7172
E-mail: dsiamerica@dsiamerica.com
www.dsigroundsupport.com

DSI Ground Support
214 Railroad Street
Winber, PA 15963
Phone +1-814-467-7030
Fax +1-814-467-7031
E-mail: dsiamerica@dsiamerica.com

DSI Ground Support
4200 Highway 22 East
Suite 7 Bay #8
Blairsville, Pa. 15717
Phone +1-724-676-2000
Fax +1-724-676-2100
E-mail: dsiamerica@dsiamerica.com

Mexico
DSI Anclas Mineras S.A. de C.V.
Industria del Vestido # 2153
Zapopan, Jalisco - Mexico 45132
Phone +52-33-3656-5588
Fax +52-33-3656-5598
E-mail: dsiamerica@dsiamerica.com
www.dsigroundsupport.com


HOUSE

Esplanade Riel Pedestrian Bridge, Winnipeg, Canada

DSI Holding GmbH

Dywidagstrasse 1
85609 Aschheim
Germany
Phone +49-89-30 90 50-200
Fax +49-89-30 90 50-252
E-mail: info@dywidag-systems.com
www.dywidag-systems.com

RHQ Americas

DYWIDAG-SYSTEMS
INTERNATIONAL USA INC.
320 Marmon Drive
Bolingbrook, IL 60440
USA
Phone +1-630-739 11 00
Fax +1-630-972 96 04
E-mail: dsiamerica@dsiamerica.com
www.dsiamerica.com

RHQ Europe

DYWIDAG-SYSTEMS
INTERNATIONAL GMBH
Siemensstrasse 8
85716 Unterschleissheim
Germany
Phone +49-89-30 90 50-100
Fax +49-89-30 90 50-120
E-mail: dsihv@dywidag-systems.com
www.dywidag-systems.com

RHQ Underground

DYWIDAG-SYSTEMS
INTERNATIONAL PTY. LTD.
P.O. Box 370
Charlestown NSW 2290, Australia
25 Pacific Highway
Bennetts Green NSW 2290
Phone +61-2-49 48 90 99
Fax +61-2-49 48 40 87
E-mail: dsi@dywidag.com.au
www.dsiminingproducts.com

ARGENTINA
AUSTRALIA
AUSTRIA
BELGIUM
BOSNIA AND HERZEGOVINA
BRAZIL
CANADA
CHILE
COLOMBIA
COSTA RICA
CROATIA
CZECH REPUBLIC
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HONG KONG
INDONESIA
IRAN
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JAPAN
KOREA
LEBANON
LUXEMBOURG
MALAYSIA
MEXICO
NETHERLANDS
NORWAY
OMAN
PANAMA
PARAGUAY
PERU
POLAND
PORTUGAL
QATAR
SAUDI ARABIA
SINGAPORE
SOUTH AFRICA
SPAIN
SWEDEN
SWITZERLAND
TAIWAN
THAILAND
TURKEY
UNITED ARAB EMIRATES
UNITED KINGDOM
URUGUAY
USA
VENEZUELA

www.dywidag-systems.com

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