



# Post-Tensioning Systems





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# About Us

## History

Today, DYWIDAG is a globally active supplier of innovative systems and technologies for the construction industry.

DYWIDAG's origins go back to the foundation of Dyckerhoff & Widmann AG in 1865 and thus to the beginnings of industrial construction.

## Tradition

Our long tradition began in 1950 with the distribution of know-how developed by Dyckerhoff & Widmann AG. The strong growth and increasing globalization in the distribution of innovative DYWIDAG systems led to the bundling of activities within a specialized organizational unit in 1979.

The DYWIDAG Group was founded to market DYWIDAG systems and technical know-how worldwide and to develop new innovative systems through its own R&D activities, thereby expanding the products and systems offered. From the very beginning, DYWIDAG has been internationally active. We are operating in the fields of Post-Tensioning, Geotechnical Engineering and Lifespan Management.

## Dywidag technology

DYWIDAG develops, produces and distributes Post-Tensioning Systems for the most demanding requirements worldwide.

DYWIDAG and SUSPA Post-Tensioning Systems are characterized by their excellent load-bearing capacity as well as the durability and clear design of the systems. They enable safe, efficient and economical use in prestressed concrete.

Our post-tensioning systems are extremely versatile and have been known by our customers for their reliability for decades.

DYWIDAG and SUSPA Strand Post-Tensioning Systems are used worldwide for bridges, buildings and dams. Due to the variable number of strands, our systems offer a high degree of flexibility and are always adapted to the individual needs of our customers.

DYWIDAG Bar Tendons have stood for excellent technology, quality and reliability for decades. Today, bar tendons are mainly used in the field of repair and reinforcement.

DYWIDAG and SUSPA Post-Tensioning Systems are tested according to European Directives and are certified according to European Technical Assessments (ETA).

Tensioned cables are used worldwide in bridge construction. Depending on the project, customers can choose either the DYNA Bond® or the DYNA Grip® stay cable system. In addition, DYWIDAG also develops monitoring systems, such as the DYNA Force® sensor system, to ensure a complete and economically cost-effective monitoring of the stay cable systems.

## Comprehensive service

DYWIDAG's global presence is based on a decentralized corporate structure. With its own companies, licensees and agents in over 90 countries, DYWIDAG is represented on all continents. This means that you, our local customers, can reach us directly at any time.

We advise project-involved planners and engineering offices on implementation and are happy to provide CAD drawings and dimensioning aids at any time. On

request, we support our customers in instructing the construction site personnel on site and, if necessary, also take over the complete installation of our products and systems in selective markets.

As a leading system supplier, we can also provide the entire equipment technology for safe and smooth installation on request.

For example, we rent and sell Prestressing jacks or grout mixers with the appropriate accessories. Of course, our services also include the professional calibration, maintenance and repair of all equipment.

## DYWIDAG – Today

Today, DYWIDAG is the market leader in the development, production and supply of Post-Tensioning Systems and Geotechnical Systems as well as Concrete Accessories for the construction industry. More than 1,350 highly motivated employees worldwide develop, produce and install innovative products and systems that meet the highest quality standards.

DYWIDAG is represented in more than 90 countries and thus on all continents either by its own DYWIDAG companies or through licensees and agents. Our products and systems are manufactured locally in over 15 production facilities worldwide. This local presence, combined with globally available know-how, forms the strength of the DYWIDAG network in accordance with our vision.

**SAFER, STRONGER, AND SMARTER.**

### Research and development

We actively drive new technical developments and research projects. Worldwide patent applications prove our leading position and are the cornerstone of our successful work - for your benefit. With our range of innovative products and systems, which always meet the highest quality standards, we offer sustainable solutions that meet the continuously changing requirements of our target markets. It is our declared goal to always be at least one step ahead in this exciting environment of technical development.

### Customer focus

We put the needs and requirements of our customers and business partners first. We offer our customers the advantages of an internationally recognized system supplier with a comprehensive product range that is optimally adapted to local needs.

### Sustainability

We are committed to sustainability at all levels and everywhere. For DYWIDAG, sustainability means finding the right balance between financial and economic performance, social concerns and our environment.

### Ethic values

DYWIDAG is known throughout the world as a strong business partner and supplier. Our customers enjoy working with us because we meet their expectations. Our employees enjoy working for DYWIDAG - because we respect and trust each other. This helps us to provide our services.

The foundation of this development is our well-deserved reputation for integrity, honesty and ethical behavior in our business relationships and at our workplaces. We stand by our values and have a zero-tolerance strategy towards unethical behavior and violations of the law.



## Milestones



**1904**

- Railway bridges near Kempten, Germany
- Tamped concrete, longest span: 64.50 m



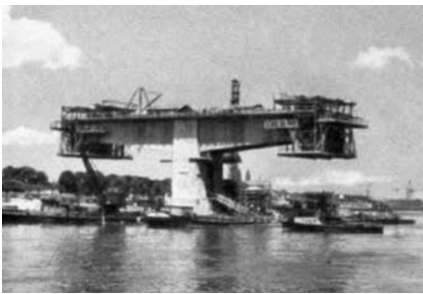
**1925**

- Construction of planetariums, System Zeiss- DYWIDAG
- Nuremberg, Dresden, Berlin, Germany



**1927**

- Saalebrücke Alsleben, Germany
- First bridge with prestressed iron tension band, developed by Dr. Ing. Franz Dischinger



**1953**

- First prestressed concrete bridge over the Rhine: The Nibelungen Bridge, Worms, Germany
- Longest span: 114 m



**1964**

- Bendorf Bridge, Germany
- A new world record in prestressed concrete: length: 524.70 m



**1970**

- BMW administration building Munich, Germany
- 100 m high hanging house with 72,000 m<sup>2</sup> usable area. Construction of the floors at ground level, then lifting them to their final position using the DYWIDAG Bar Post-Tensioning System
- DYWIDAG Bar Post-Tensioning System and DYWIDAG Lifting Method





### 1975

- Construction of the CN-Towers, Toronto, Canada
- 550 m high television tower with restaurant platform. Upper tower shaft made of DYWIDAG Prestressed Concrete



### 1988

- Olympic Bridge, Seoul, Korea
- Development, production, delivery and installation of DYWIDAG stay cables



### 2002

- Chancellor's Office Berlin
- Largest German application of monostrands



### 2004

- Snøhvit, Melkøya, Norway
- Supply and installation of 1,650 t cryogenic strand tendons for the construction of four LNG tanks



### 2012

- Harbor Drive Pedestrian Bridge, San Diego, CA, USA
- DYWIDAG supplies Post-Tensioning Systems for one of the longest self-anchored pedestrian suspension bridges in the world. This project was awarded the "Best of the Best" prize by Engineering News Record (ENR)



### 2013

- Optimization of prestressing systems for the construction of prestressed concrete and hybrid towers for wind turbines
- Supply and installation of more than 1,000 wind turbines on 4 continents in the following years



### 2014

- Chao Praya Bridge, Thailand
- Development, supply and installation of extradosed DYWIDAG Cable Systems
- Installation of a global monitoring system and initial installation of the DYNA® Link anchor box



### 2018

- Gaildorf wind farm
- Completion of the wind turbine with the world's highest hub height of 178 m (natural power storage)
- Supply of SUSPA EX and DYWIDAG Strand Tendons



### 2018

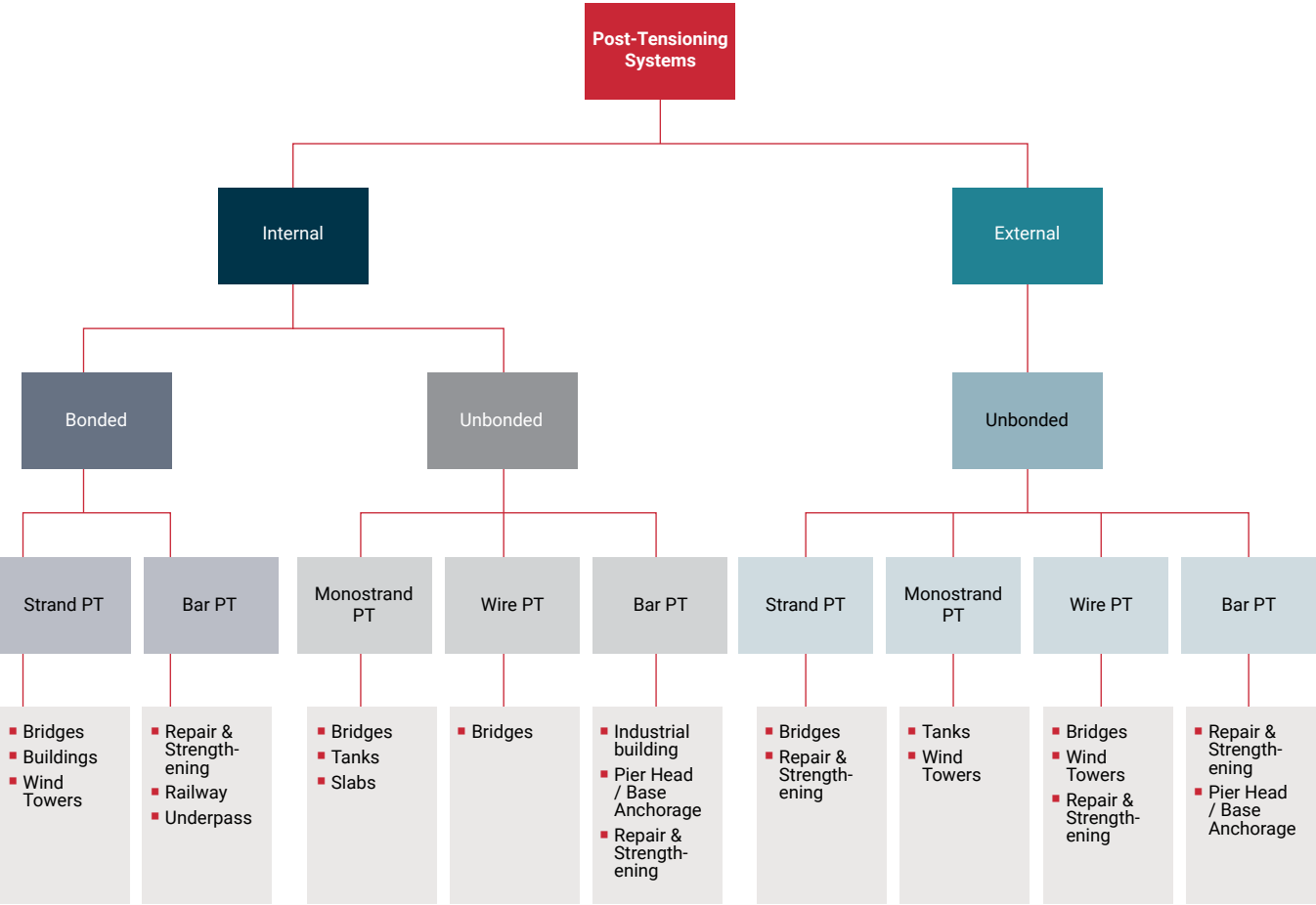
- Bridge A59 over the Wupper, Leverkusen
- Supply and installation of DYWIDAG Bar Tendons and SUSPA-Wire EX Tendons to reinforce the bridge deck

# Post-Tensioning Design

Prestressing of components generates compressive stresses counteracting tensile stresses from loads and constraints. This largely avoids cracking in concrete members in the serviceability state. High-strength prestressing steel tensile elements in the form of strands, wires or bars are used for stressing.

Prestressing of concrete members with immediate bond, restricted to straight-line tensile elements only, requires a production plant and is therefore usually used for prestressed precast concrete units.

Bonded or unbonded, internal or external post-tensioned tendons are used for any tendon course, high stressing forces and stressing on-site.





## Bonded post-tensioning

In case of bonded post-tensioned members, the tendons initially lie slack in ducts during concreting or are inserted into empty ducts of the already concreted members.

Besides sheet metal ducts, DYWIDAG offers plastic ducts as well.

After sufficient curing of the concrete, the tendons are stressed against the concrete. Then the ducts are grouted with cement grout. Grouting develops bond between the tendons and the concrete and additionally provides corrosion protection due to the alkaline cement grout.

The stressing anchorage must be fully accessible for the stressing process, whereas the fixed anchor can be located anywhere within the structure.

Strand tendons with up to 55 strands can be installed in virtually any geometry. Plate anchorages and multi-plane anchorages are available for anchoring. Further, bond anchors are also possible with anchors cast-in concrete.

At construction joints, non-continuous tendons can be stressed by means of couplers in the already concreted construction section and then strands can be fixed for the subsequent construction section.

Bar tendons are applied for short and mainly straight tendon courses. The low-slip anchorage with nuts allows for low losses of prestressing force, even with short bars.

## Internal unbonded post-tensioning

Post-tensioning of unbonded internal tendons follows the principles of bonded post-tensioning. Instead of grouting with cement grout, the tendons are protected against corrosion before or after stressing with grease or similar corrosion protection compounds in plastic sheaths. Tendons consisting of bundled, greased and PE-sheathed monostrand tendons are used in building construction and for transversal post-tensioning of bridges.

Systems with double PE sheathing are used in case the monostrands shall be exchangeable or shall satisfy special requirements. Internally unbonded longitudinal post-tensioning with monostrands is technically feasible, but with the amount of typically required prestressing steel, this leads to a strong cross-sectional weakening, which must be considered in the shear force design.

Therefore, compact bundles of parallel wires in thick-walled plastic ducts are preferred for unbonded longitudinal post-tensioning. For internal unbonded tendons, a stressing force check is possible by means of lift-off tests or built-in load cells. If required, these tendons can also be re-stressed later provided the stressing anchors are accessible.

## External post-tensioning

External tendons are guided outside the concrete cross-section and either run straight between the end anchorages or are deflected at cross beams, saddles etc.

Tendons for external prestressing consist of individual PE-coated strands protected against corrosion by grease, which are bundled in a PE pipe or wire bundles in grease filled sheaths.

External tendons with strands and wires are used in bridge construction and for prestressing of wind farms with concrete and hybrid towers.

External bar tendons are mainly used for strengthening of buildings. A major field of application here is strengthening against shear stress, whereby bar tendons are arranged vertically outside the webs and can replace missing stirrup reinforcement accordingly.

# Internal Bonded Post-Tensioning Systems

## Ducts

### Metal sheet ducts

- Round
  - Strand and Bar
- Flat
  - Strand up to 5 strands only



### PE/PP-Ducts

- Round
  - Strand and Bar
- Flat
  - Strand up to 5 strands only





# Bonded Strand Tendons

## Applications

- Bridges
- Tanks & Silos
- Slabs

## Features

- Prefabrication or On-site Production possible
- Electrically isolated Version available
- Cryogenic Application
  - LNG-Tanks
- Metal Sheet or Plastic Ducts available
  - Round
  - Oval

## Main characteristics

Minimum Tendon Size	1 Strand
Maximum Tendon Size	55 Strands
Steel Grade of Strands	Y1770, Y1860
Strand Diameter	0.5", 0.6", 0.62"
Corrosion Protection	Cement Grout, Special Grout
Replacement possible	No
Restressing possible	No
Coupling possible	Yes
Possible Tendon Course	Curved and straight





# Anchorage

## Multiple anchorage MA – Standard application up to 22 strands

- 5-22 Strands
- Helix not required
- Minimum Concrete Compressive Strength from 34 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Longitudinal Post-Tensioning of Beams and Bridges
- Horizontal Post-Tensioning of Tanks (Silos, LNG)
- ETA-13/0815
- ETA-13/0839

### DYWIDAG System



### SUSPA System



## Multiplane anchorage MA – Application with 27 or more strands and special application

- 5-55 Strands
- Optimized Center Distances compared to Standard Application by Use of Helical and Stirrup Reinforcement
- Electrically isolated Version available
- Minimum Concrete Compressive Strength already from 25 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Longitudinal Post-Tensioning of Bridge Girders
- Horizontal Post-Tensioning of Tanks (Silos, LNG)
- ETA-13/0815
- ETA-13/0839

### System DYWIDAG with helix



### System SUSPA with helix



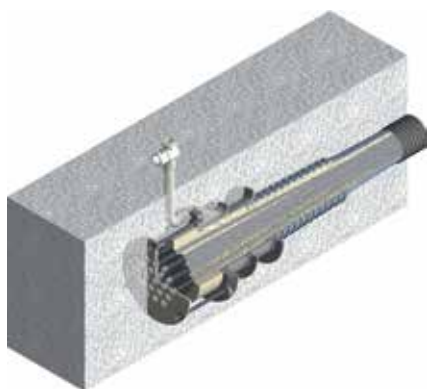
### Electrically isolated



## Fixed anchorage MP – Standard application up to 22 strands

- 5-22 Strands
- In Conjunction with SUSPA System MA Stressing Anchorage
- Immediate Casting in Concrete possible - Reduced Formwork Expenditure
- Minimum Concrete Compressive Strength from 34 N/mm<sup>2</sup> (Cube)
- Preferred Fixed Anchorage for Prefabricated Tendons in Bridges
- ETA-13/0839

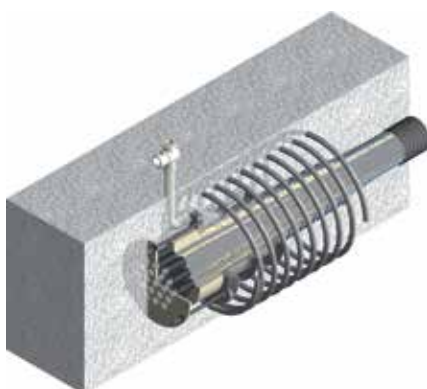
### System SUSPA



## Fixed anchorage MP – Special application

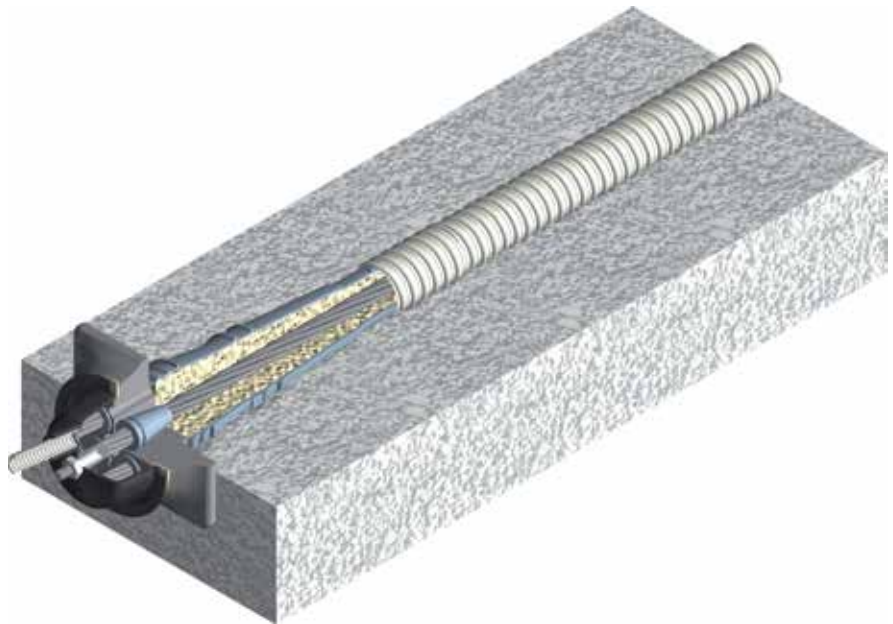
- 5-22 Strands
- In Conjunction with SUSPA System MA Stressing Anchorage
- Center Distances optimized by Installation of Helical Reinforcement compared to Standard Application
- Minimum Concrete Compressive Strength already from 25 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Prefabricated Tendons in Bridges
- ETA-13/0839

### System SUSPA



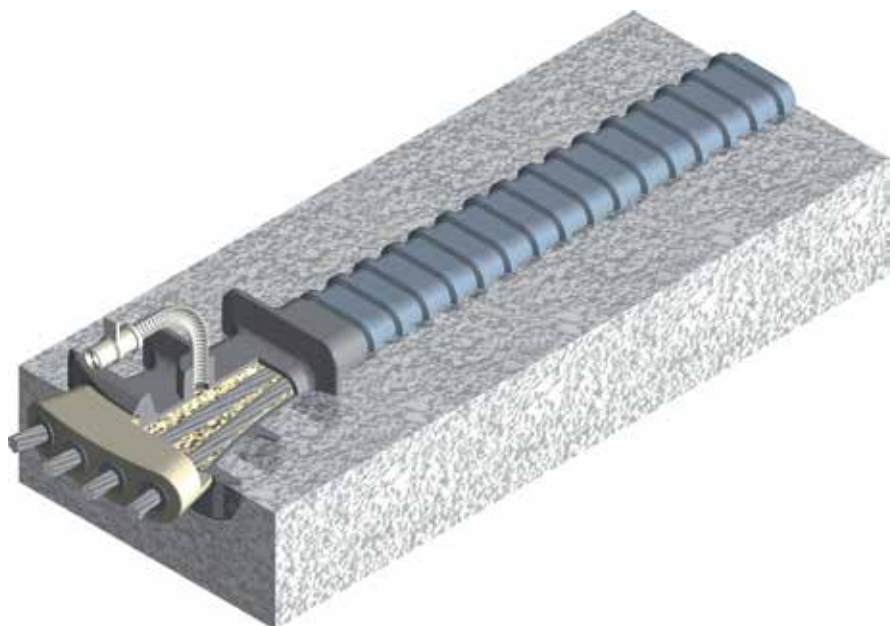
## Plate anchorage SD

- 3-9 Strands
- ETA-13/0815
- Minimum Concrete Compressive Strength from 30 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Transversal Post-Tensioning in Bridges, Floor Slabs, Tanks and Silos



## Flat multiplane anchorage FMA

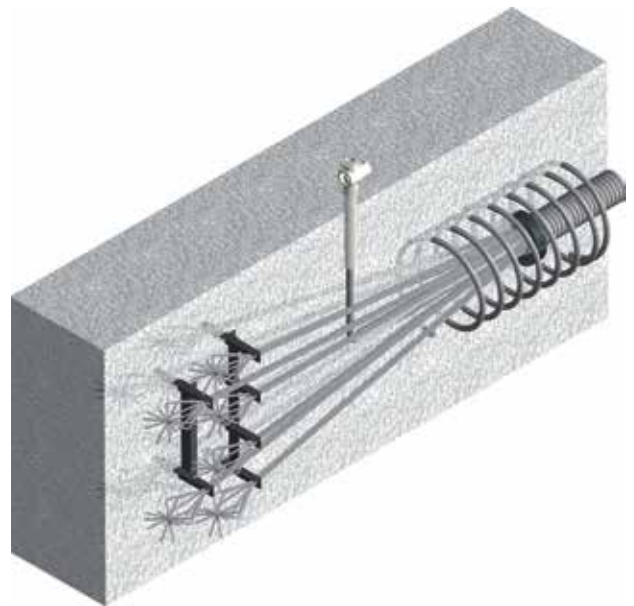
- 2-5 Strands
- Minimum Concrete Compressive Strength from 25 N/mm<sup>2</sup> (Cube) at Time of Stressing
- For Floor Slabs





## Bond head anchorage HL/HR

- 3-22 Strands
- Cast-in Fixed Anchorage
  - Reduced Formwork Expenditure
- Minimum Concrete Compressive Strength from 34 N/mm<sup>2</sup> (Cube) at Time of Stressing
- ETA-13/0839



## Loop anchorage HV

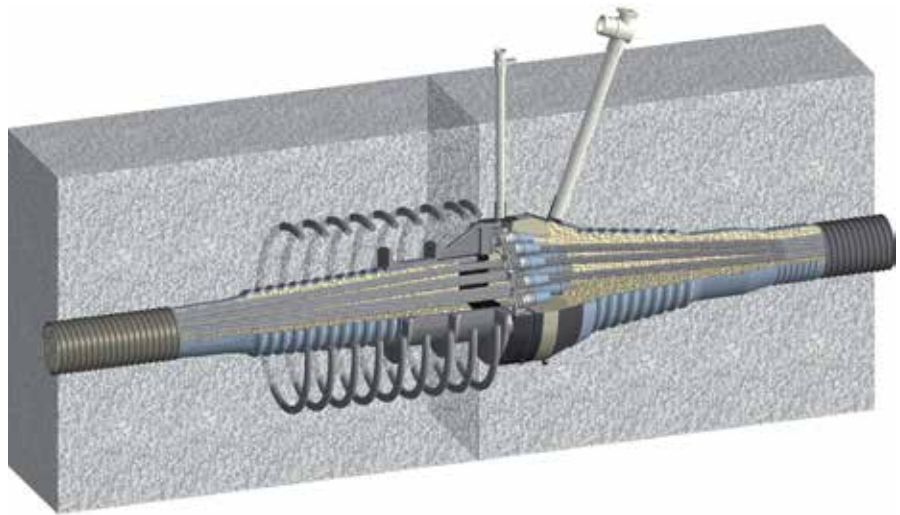
- 3-22 Strands
- Vertical Tendons for Tanks
- Minimum Concrete Compressive Strength from 28 N/mm<sup>2</sup> (Cube) at Time of Stressing
- German Approval Z-13.1-148



# Coupler

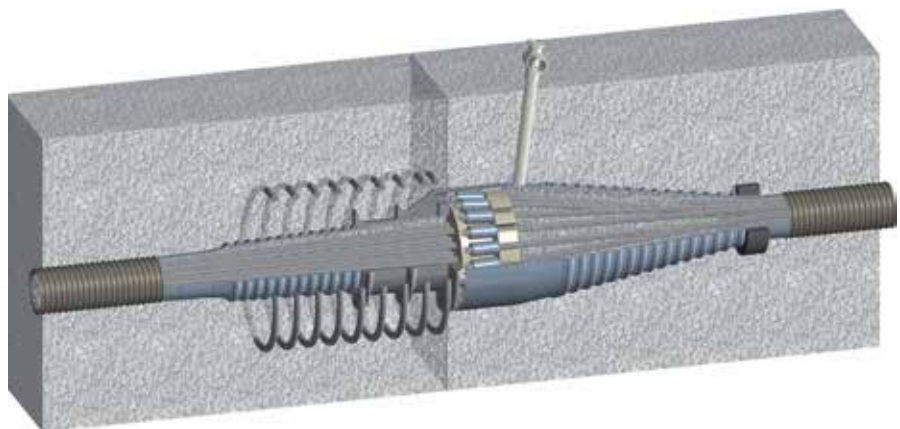
## Coupler R

- 5-37 Strands
- Fixed Coupler
- Prefabricated
- Bridges
- ETA-13/0815



## Coupler K

- 3-22 Strands
- Quick Installation in Conjunction with Compression Fittings
- Fixed Coupler
- Enables Electrically Isolated Execution
- Bridges
- ETA-13/0839



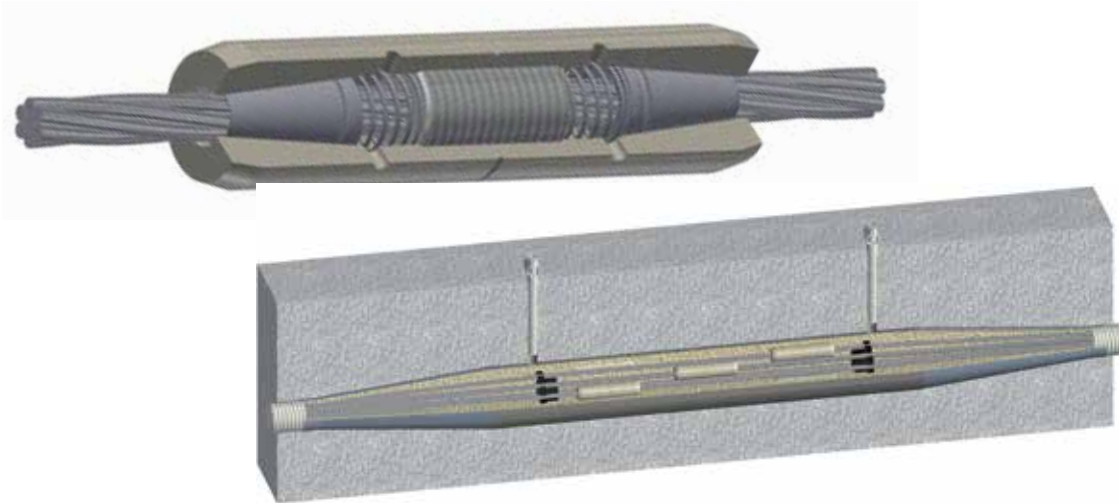


## Coupler D

- 5-37 Strands
- Movable Coupler

- Bridges

- ETA-13/0815

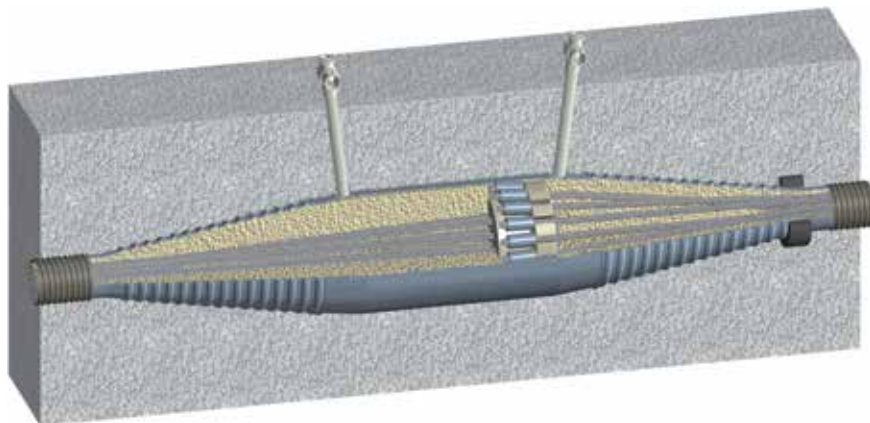


## Coupler V

- 3-22 Strands
- Quick Installation in Conjunction with Compression Fittings

- Movable Coupler
- Enables Electrically Isolated Execution

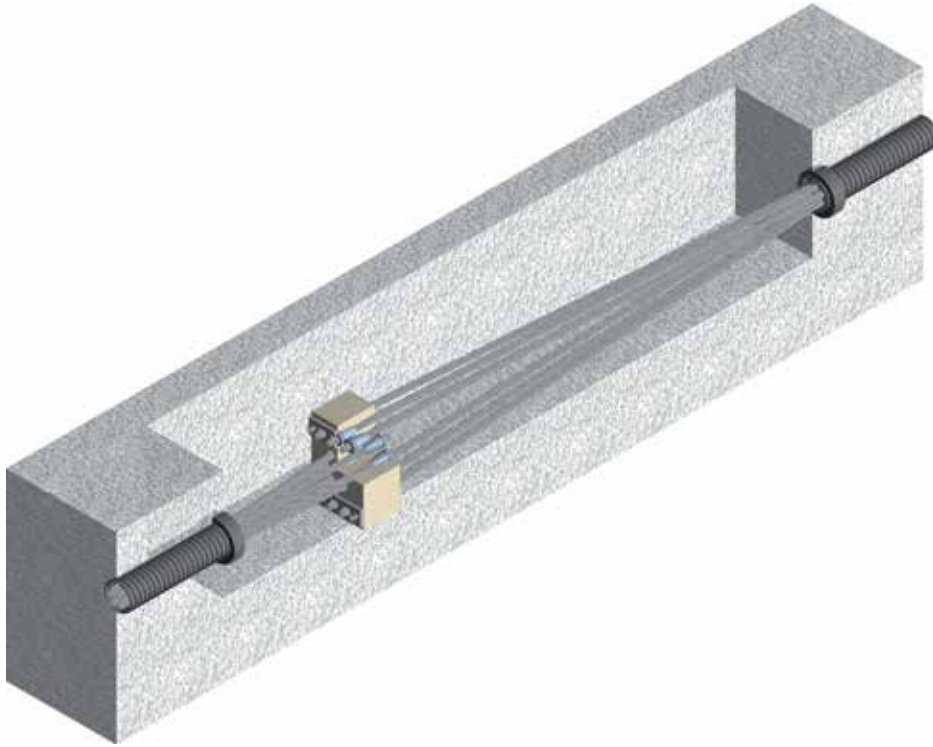
- Bridges
- ETA-13/0839





## Floating anchorage block MZ

- 2-8 Strands
- Post-Tensioning of Tanks
- ETA-13/0839
- Fixed Floating Anchorage Block



## Coupler M/ME

- 1-12 Strands
- Movable Coupler
- Tanks and Strengthening of Pipelines



# Bonded Bar Tendons

## Applications

- Connection of Precast Members
- Tensioning of Launching Noses
- Fixation or Tie-back Anchorage of Steel Structures
- Transversal Post-Tensioning
- Strengthening of buildings, bridges, and civil engineering structures

## Features

- Low slip Anchorages
- WS Bar Tendons for short Lengths < 2,5 m
- WR Bar Tendons for Lengths > 2,5 m
- Possible with Metal Sheet or Plastic Duct

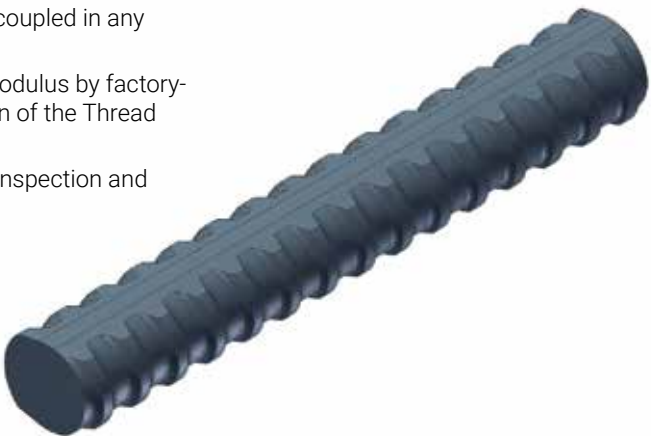
## Main characteristics

Minimum Tendon Size	18 mm
Maximum Tendon Size	75 mm
Steel Grade of Bar	Y1030, Y1050
Bar Types	WR/WS
Corrosion Protection	Cement Grout, Special Grout
Replacement possible	No
Restressing possible	No
Coupling possible	Yes
Possible Tendon Course	Mainly straight

# Bars Types

## WR

- Diameter 18-75 mm
- Continuous hot-rolled Thread
- Coarse Thread – robust and appropriate for on-site Conditions
- Available for a large Range of Diameter
- Can be divided and coupled in any Section
- Constant Young's Modulus by factory-controlled Elongation of the Thread Bar Steel
- Continuous Quality Inspection and Control



### WR bar types

Designation	Unit	Bar Types								
		18 WR	26 WR	32 WR	36 WR	40 WR	47 WR	57 WR	65 WR	75 WR
Nominal diameter	mm	17.5	26,5	32	36	40	47	57	65	75
Nominal cross sectional area	mm²	241	552	804	1,018	1,257	1,735	2,581	3,331	4,418
Characteristic breaking load	kN	255	580	845	1,070	1,320	1,820	2,671	3,447	4,572
Maximum initial stressing force <sup>1)</sup> $P_{m0,max} = S_n \times 0.8 \times f_{p,k}$	kN	204	464	676	856	1,056	1,457	1,940	2,502	3,321
Max. overstressing <sup>2)</sup> $P_{0,max} = S_n \times 0.95 \times f_{p0,1k}$	kN	219	499	722	912	1,131	1,566	2,047	2,641	3,508
ETA-05/0123	–	X	X	X	X	X	X			
Z-13.71/72/73-50123	–	X	X	X	X	X				

<sup>1)</sup> The specified values relate to maximum values according to EN 1992-1-1, e.g. ( $k_1 \times f_{p,k}$ ,  $k_2 \times f_{p0,1k}$ ).  
<sup>2)</sup> Overstressing is allowed in case the stressing jack can be read with a precision of  $\pm 5\%$  (possible outside of Germany).





## WS

- Diameter 26-40 mm
- Cold-rolled Thread on either Side – low Anchorage Slip
- Constant Young's Modulus by factory-controlled Elongation of the Thread Bar Steel
- Continuous Quality Inspection and Control



### WS bar types

Designation	Unit	Bar Types			
		26 WS	32 WS	36 WS	40 WS
Nominal Diameter	mm	26.5	32	36	40
Nominal cross sectional area	mm <sup>2</sup>	552	804	1,018	1,257
Characteristic breaking load	kN	580	845	1,070	1,320
Maximum initial stressing force <sup>1)</sup> $P_{m0,max} = S_n \times 0.8 \times f_{p,k}$	kN	464	676	856	1,059
Maximum over stressing force <sup>2)</sup> $P_{0,max} = S_n \times 0.95 \times f_{p0,1k}$	kN	499	722	912	1,131
ETA-05/0123	–	<sup>3)</sup>	X	X	<sup>3)</sup>
Z-13.71/72/73-50123	–	<sup>3)</sup>	X	X	<sup>3)</sup>

<sup>1)</sup> The specified values relate to maximum values according to EN 1992-1-1, e.g. ( $k_1 \times f_{p,k}$ ,  $k_2 \times f_{p0,1k}$ ).

<sup>2)</sup> Over stressing is allowed in case the stressing jack can be read with a precision of  $\pm 5\%$  (possible outside of Germany).

<sup>3)</sup> Without approval



## Anchorage

### SYSTEM OVERVIEW

Designation	Anchor Plate	WR Bar Type									WS Bar Type			
		18 WR	26 WR	32 WR	36 WR	40 WR	47 WR	57 WR	65 WR	75 WR	26 WS	32 WS	36 WS	40 WS
Bonded bar tendon with QR-plate anchorage <b>with</b> additional reinforcement	2074		X	X	X	X							X	
Bonded bar tendon with small solid rectangular plate anchorage <b>with</b> additional reinforcement	2076	X	X	X	X	X	X				X	X	X	X
Bonded bar tendon with QR-plate anchorage <b>without</b> additional reinforcement	2074		X	X	X	X							X	
Bonded bar tendon with small solid rectangular plate anchorage <b>without</b> additional reinforcement	2076	X	X	X	X	X	X				X	X	X	X
Bonded bar tendon with small solid square plate anchorage <b>without</b> additional reinforcement	2011	X	X	X	X	X	X	X	X	X	X	X	X	X
Bonded bar tendon with solid rectangular plate anchorage <b>with</b> additional reinforcement	2012	X	X	X	X	X	X				X	X	X	X

### Anchor plates

**Solid square plate without additional reinforcement**  
2011

2011



**Solid rectangular plate with additional reinforcement**  
2012

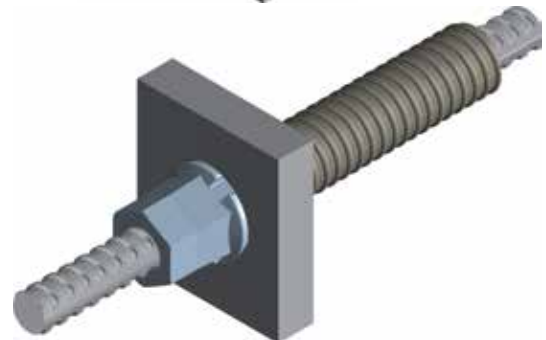
2012



2074



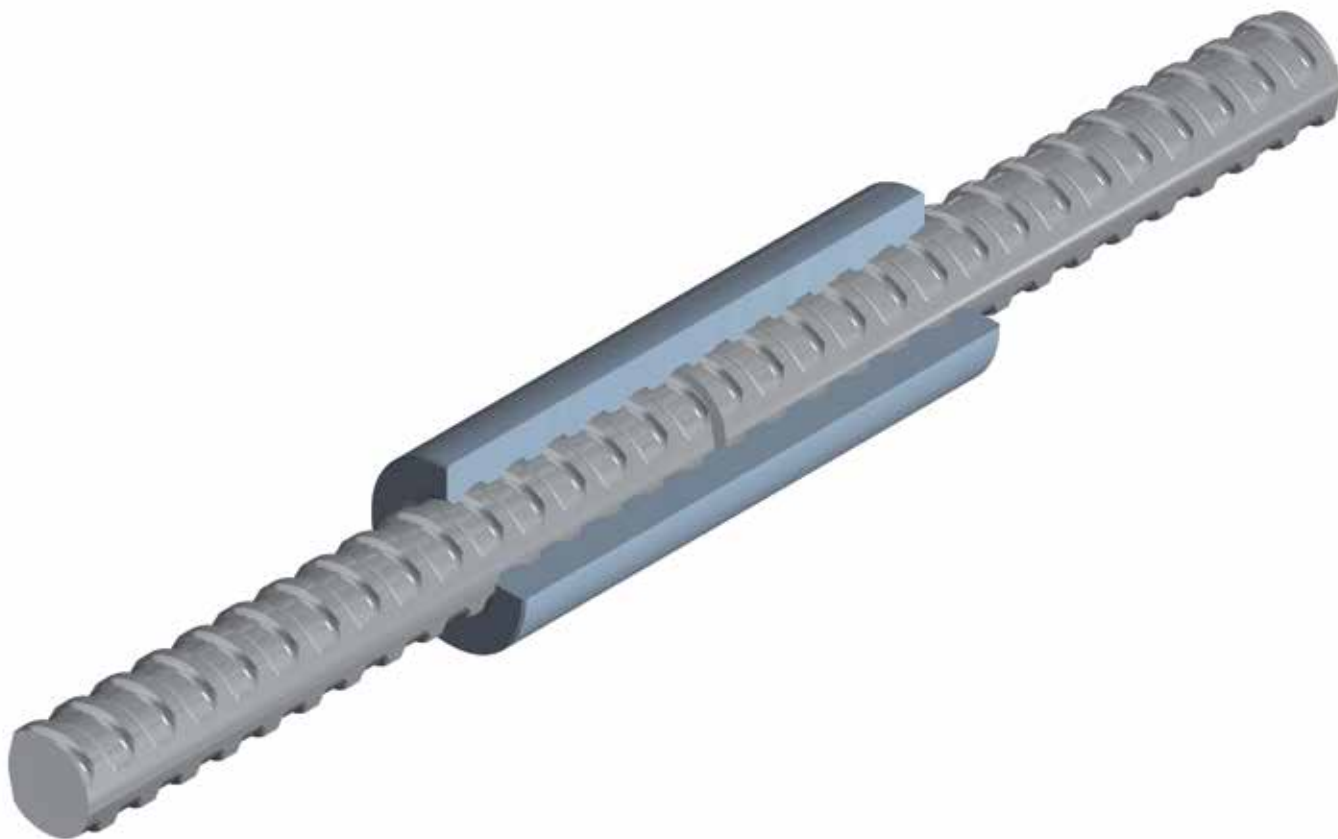
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## Coupler

### Standard application

Coupling with equal diameter of the same bar type



### Special application – extension and strengthening of existing structures

1. Coupling with equal diameter of different bar types
  - Connection of a plain bar with cold-rolled thread to an existing thread bar for minimizing anchorage slip
2. Coupling of the same bar type but with different diameter
  - For strengthening or extension of existing structures
  - Also applicable for connection to former bar types in existing structures



# Internal Unbonded Post-Tensioning Systems

- Internal unbonded tendons are not rigidly bonded to surrounding concrete.
  - Low induced stress range
  - Less fretting fatigue
  - Monitoring of stressing forces
  - Restressing possible, if required
  - Replaceable, if required
- Grease, wax, or gel in a plastic duct provides corrosion protection
- Corrosion protection is usually prefabricated with the tendon, delivered to site, and installed
- Highest quality of corrosion protection in case of prefabrication
  - Requirements for crack widths as on reinforced concrete members
  - More favorable conditions for decompression check





# Internal Unbonded Strand Tendons

## Applications

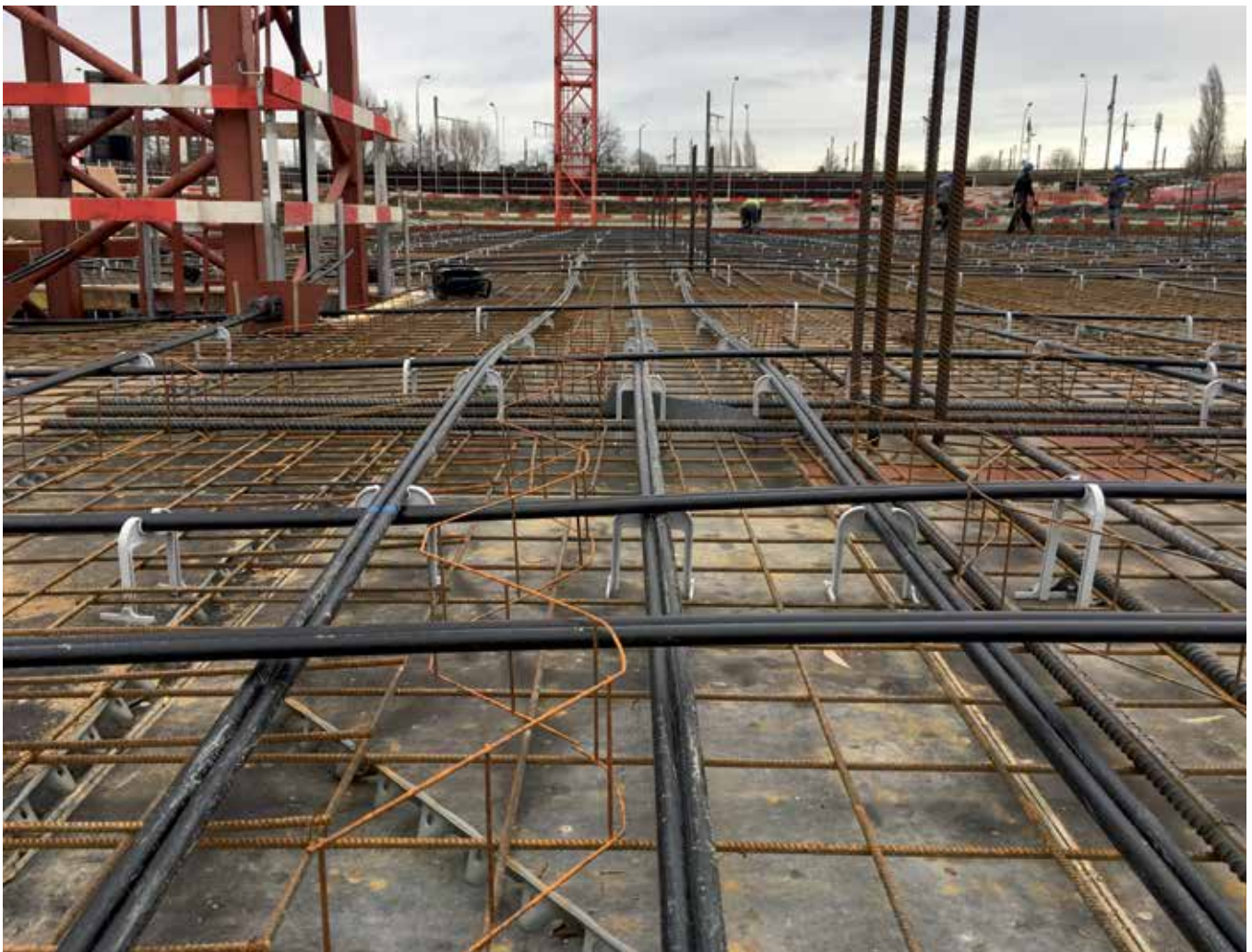
- Bridges
- Containers (e.g. Tanks, Silos)
- Slab Systems

## Features

- Factory or on-site Production possible
- Electrically isolated Version available

## Main characteristics

Minimum Tendon Size	1 Strand
Maximum Tendon Size	55 Strands
Steel Grade of Strands	Y1770, Y1860
Strand Diameter	0.5", 0.6", 0.62"
Corrosion Protection	Cement Grout, Special Grout
Replacement possible	System-dependent
Restressing possible	System-dependent
Coupling possible	Yes
Possible Tendon Course	Curved and straight



# Monostrand Tendons

## Applications

- Bridges, Transversal and – occasionally – longitudinal Post-Tensioning
- Tanks, Ring Tendons
- Buildings, Slab Systems

## Features

- Factory or on-site production possible
- No grouting operations required on site
- High-quality prefabricated  
Monostrands do not require additional ducts to ensure corrosion protection
- Additional PE-sheathing for bridges in case the option for replacement is required

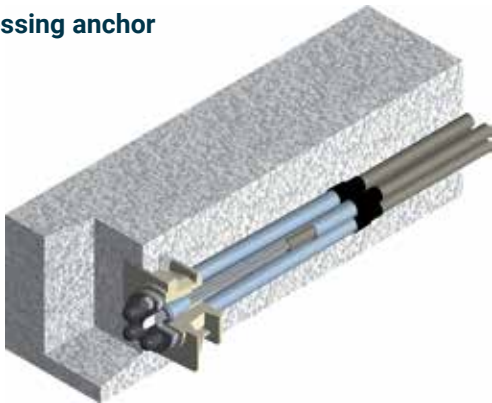
## Main characteristics

Minimum Tendon Size	1 Strand
Maximum Tendon Size	7 Strands
Steel Grade of Strands	Y1770, Y1860
Strand Diameter	0.6", 0.62"
Corrosion Protection	PE-Sheathing and Corrosion Protection Compound
Replacement possible	Yes
Restressing possible	Yes
Coupling possible	Yes
Possible Tendon Course	Curved and straight

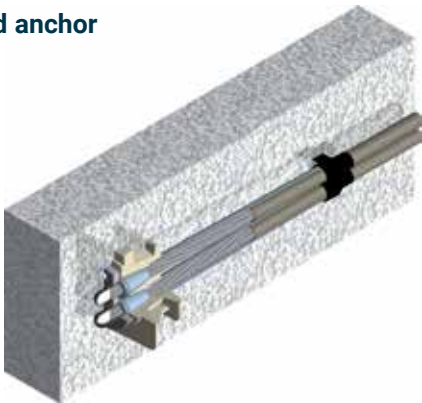
## One-piece casting for fixed and stressing anchor

- 1-7 Strands
- Z-13.2-147, ETA/19-0077
- Minimum Concrete Compressive Strength from ab 23 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Transversal Post-Tensioning in Road Bridge Slabs
- Slabs

MGS stressing anchor



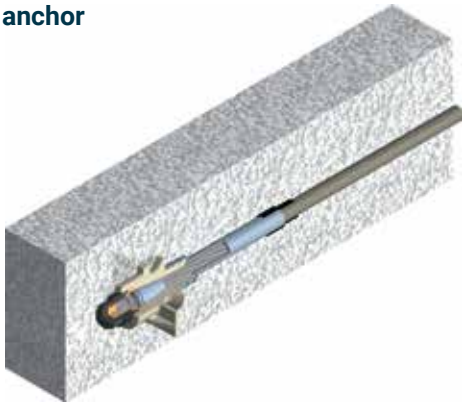
MGF fixed anchor



SKM stressing anchor



SFM fixed anchor



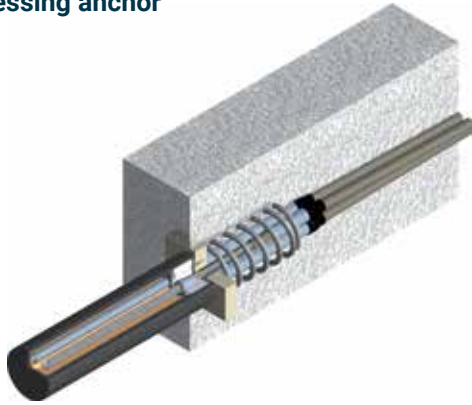


## Anchorage

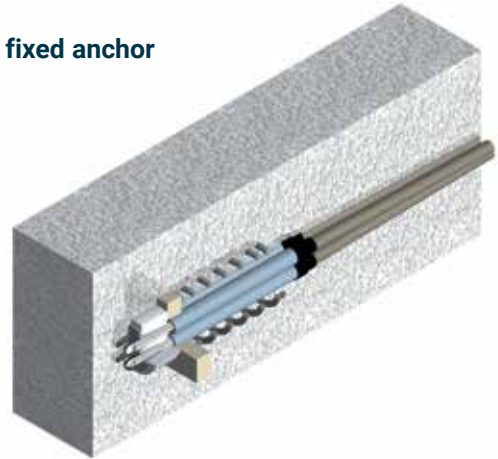
### Plate anchorages MER, MEF

- 2-5 Strands
- Z-13.2-113
- ETA-03/0036
- Minimum Concrete Compressive Strength from 20 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Replaceable and restressable longitudinal Post-Tensioning of Bridge Girders

#### MER stressing anchor



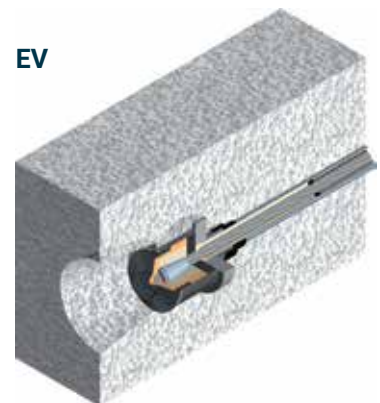
#### MEF fixed anchor



### Single anchorage in conjunction with precast concrete members

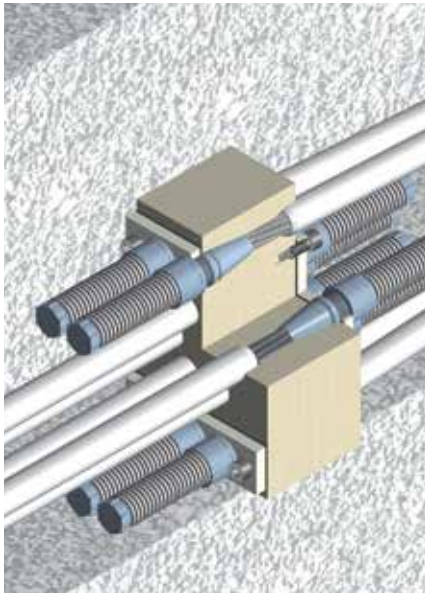
- 1 Strand
- Post-Tensioning of Tanks and Silos
- Minimum Concrete Compressive Strength from 30 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Z-13.2.95

#### EV

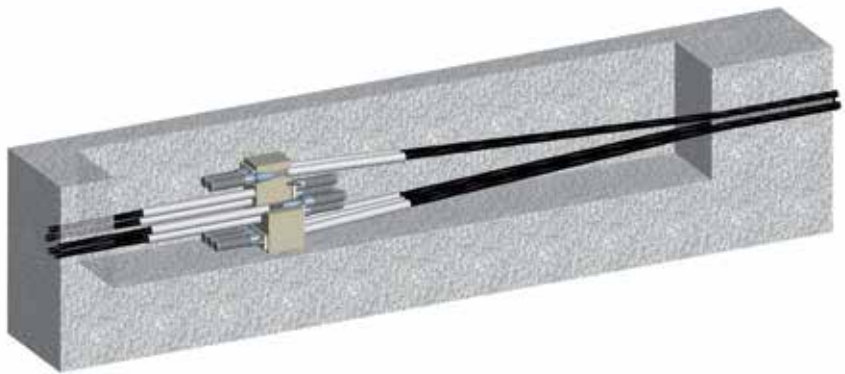


## Ring anchorage for insitu concrete solutions

- 2-12 Strands
- Minimum Concrete Compressive Strength from 30 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Post-Tensioning of Tanks and Silos
- Z-13.2.40



Anchor head MZ

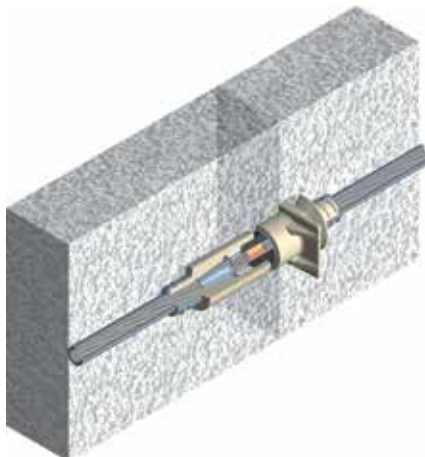


## Coupler

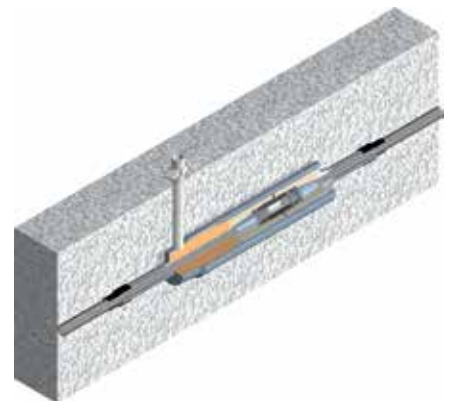
### FKM, BK

- 1-7 Strands
- Buildings
- ETA-03/0036
- Z-13.2-147

FKM fixed coupler



BK movable coupler









# Internal Unbonded Wire Tendons

## Applications

- Occasionally as longitudinal Post-Tensioning for Bridges

## Features

- Low slip
- Prefabrication
- No grouting operations required on site
- Inspectable (e.g. warning signs through the structural behavior)

## Main characteristics

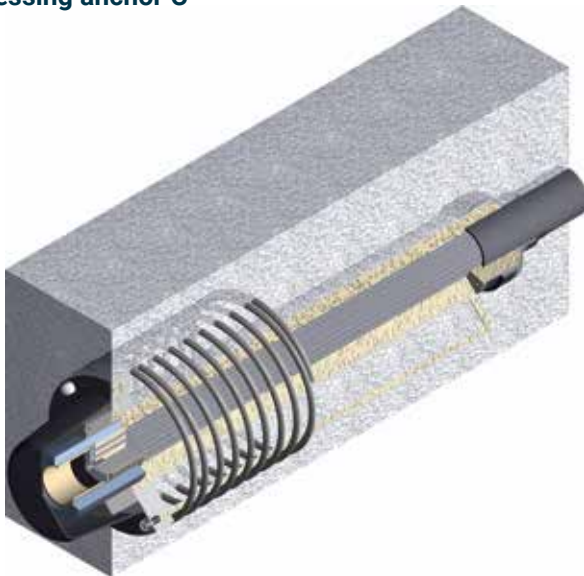
Minimum Tendon Size	30 Wires
Maximum Tendon Size	84 Wires
Steel Grade of Wires	Y1670, Y1770
Wire Diameter	7 mm
Corrosion Protection	PE-Sheathing and Corrosion Protection Compound
Replacement possible	Yes
Restressing possible	Yes
Coupling possible	Yes, provided no Replacing/Restressing is required
Possible Tendon Course	Curved and straight



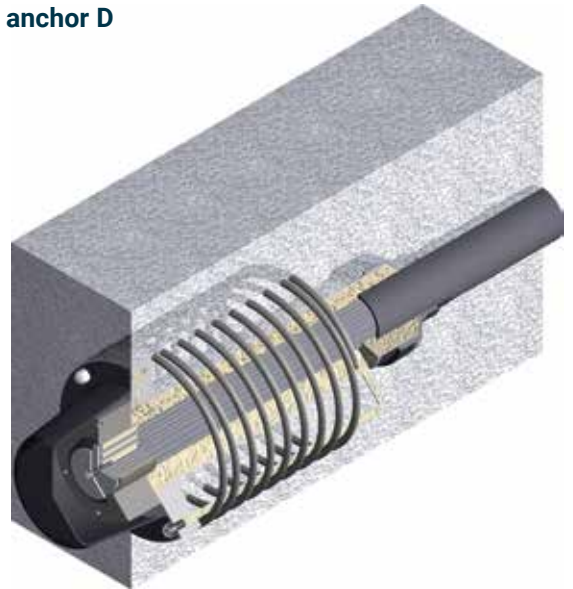
## Short description

- 30-84 Wires
- Z-13.2-109
- Minimum Concrete Compressive Strength from 33 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Longitudinal Post-Tensioning of Bridge Girders

Stressing anchor C



Fixed anchor D



# Internal Unbonded Bar Tendons

## Applications

- Connection of Precast Members
- Pier Cap and Base Anchorage
- Fixation or Tie-back Anchorage of Steel Structures
- Transversal Post-Tensioning
- Strengthening of buildings, bridges, and civil engineering structures

## Features

- Low slip Anchorages
- No grouting operations required on site
- WS Bar Tendons for short Lengths < 2,5 m
- WR Bar Tendons for Lengths > 2,5 m
- Inspectable
- ETA-05/0123 bzw. Z-13.72-50123
- Restressable

## Main characteristics

Minimum Tendon Size	18 mm
Maximum Tendon Size	47 mm
Steel Grade of Bar	Y1050
Bar Types	WR/WS
Corrosion Protection	<ul style="list-style-type: none"><li>▪ Heat Shrink Sleeve or DYNA Protect® Bar and PE-Duct</li><li>▪ Grouting with corrosion protection wax acc. to EAD16</li></ul>
Replacement possible	Yes
Restressing possible	Yes
Coupling possible	Yes
Possible Tendon Course	Mainly straight

## Bar types

### WR

- Diameter 18-47 mm
- Continuous hot-rolled Thread
- Specifications see Page 20

### WS

- Diameter 26-40 mm
- Cold-rolled Thread on either Side with low slip special Thread
- Specifications see Page 21





## Corrosion protection for unbonded bar tendons

### Injection with corrosion protection wax

- Sheathing of the PT steel with PE protection duct and filling of the annular space with corrosion protection compound
- Highest Maximum corrosion protection quality by factory production
- On-site injection possible

### DYNA Protect® Bar

- Double layer, machine-wrapped corrosion protection tape
- Commonly supplied within a PE protection duct

### Heat shrink sleeve

- Application of suitable heat shrink sleeves with glue layer on the inside
- Highest corrosion protection quality by factory production
- Commonly supplied within a PE protection duct

### Injection with cementitious grout

- Sheathing of the PT steel with PE protection duct and filling of the annular space with corrosion protection compound
- Highest corrosion protection quality by factory production
- On-site grouting possible



# Anchorage

## System overview

Designation	Anchor Plate	WR Bar Types										WS Bar Types			
		18 WR	26 WR	32 WR	36 WR	40 WR	47 WR	57 WR	65 WR	75 WR		26 WS	32 WS	36 WS	40 WS
Unbonded and external bar tendon with solid square plate anchorage <b>without</b> additional reinforcement	2011	X	X	X	X	X	X	X	X	X		X	X	X	X
Unbonded and external bar tendon with solid square plate anchorage <b>with</b> additional reinforcement	2012	X	X	X	X	X	X					X	X	X	X

## Anchor plates

- For Post-Tensioning operations already from a Concrete Compressive Strength of 25 N/mm² (Cube) (e.g. early Time of Stressing, existing structures with low concrete strength)

Solid square plate without additional reinforcement 2011



Solid square plate with additional reinforcement 2012



## Coupler

### Coupler with constant diameter

- Coupling of workshop-prefabricated and corrosion protected tendons
- Installation and grouting of the coupler on site







Internal tensioning system

Unbonded

Bar



# External Unbonded Post-Tensioning Systems

- External unbonded tendons are solely connected to the structure in the anchorage and deviation zone; there is no rigid bond to the surrounding concrete
  - Low induced stress range
  - Less fretting fatigue
  - Monitoring of stressing forces
  - Restressing possible, if required
  - Replaceable, if required
- Grease, wax, or gel in a plastic duct provides corrosion protection
  - Requirements for crack widths as on reinforced concrete members

## External Unbonded Strand Tendons

### Applications

- Bridges

### Features

- Inspectable
- On-site production of even very long tendons possible
- Electrically Isolated Version available
- Stress measurement with DYNA Force® possible

### Main characteristics

Minimum Tendon Size	3 Strands
Maximum Tendon Size	55 Strands
Steel Grade of Strands	Y1770, Y1860
Strand Diameter	0.6", 0.62"
Corrosion Protection	Corrosion protection by filling with wax or grease, and cementitious grout in a PE-duct
Replacement possible	Yes, if filled with wax or grease
Restressing possible	Yes, if filled with wax or grease
Possible Tendon Course	Straight line with deflection on a deviator possible



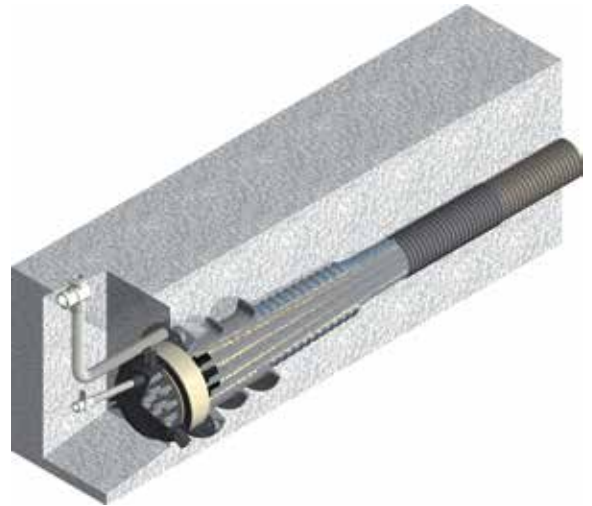
## Anchorage

### MA anchorage – standard application up to 22 strands

- 5-22 Strands
- No Helix
- Minimum Concrete Compressive Strength from 34 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Longitudinal Post-Tensioning of Bridge Girders
- ETA-13/0979



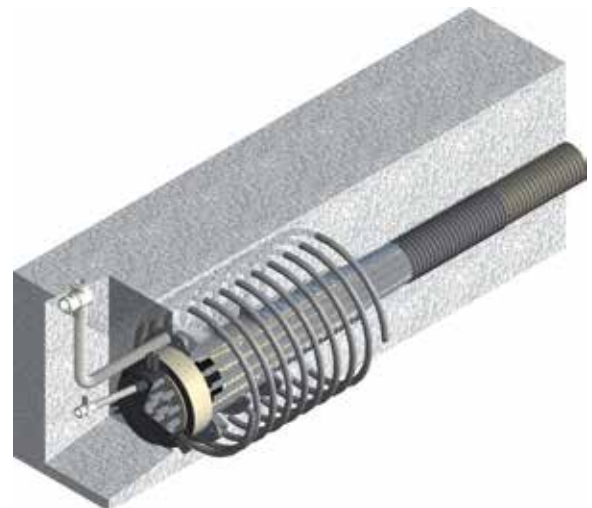
System DYWIDAG without helix



### MA anchorage – application with 27 or more strands and special application

- 3-55 Strands
- ETA-13/0979
- Optimized Center Distances compared to Standard Application by Use of Helical Reinforcement
- Minimum Concrete Compressive Strength from 25 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Longitudinal Post-Tensioning of Bridge Girders

System dywidag with helix



### Plate anchorage

- 3-55 Strands
- ETA-13/0979
- Minimum Concrete Compressive Strength from 25 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Longitudinal Post-Tensioning of Bridge Girders, Strengthening of Bridges for enhanced bending loading capacity





# External Single-Strand Tendons with Monostrands

## Applications

- Tanks and Silos
- Strengthening of girders

## Features

- Inspectable
- No grouting operations required on site
- Prefabrication or on-site production possible

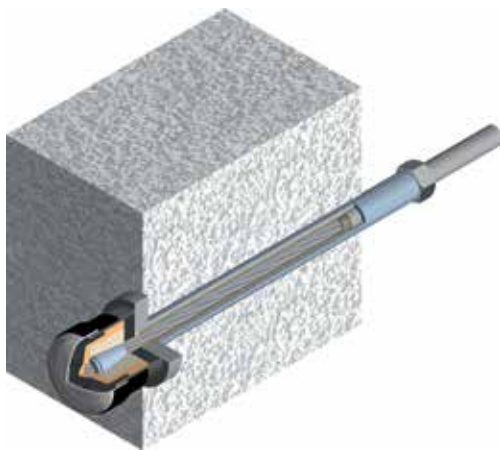
## Main characteristics

Tendon Size	1 Strand
Steel Grade of Strands	Y1770
Strand Diameter	0.6", 0.62"
Corrosion Protection	Double Layer PE-Sheathing and Corrosion Protection Compound
Replacement possible	Yes
Restressing possible	Yes
Possible Tendon Course	Curved and straight

## Anchorage

### Plate anchorage

- 1 Strand
- Z-13.3-135
- Minimum Concrete Compressive Strength from 30 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Ring tendon for tanks and silos, strengthening of girders in bridges and buildings



# External Unbonded Wire Tendons

## Applications

- Longitudinal Post-Tensioning in Bridges
- Wind Power

## Features

- Low slip
- Inspectable
- Complete prefabrication of the corrosion protected tendon up to a length of 400 m possible
- No grouting operations required on site
- Extremely small deviations possible, Deviation half shells provide easy tendon installation, even with biaxial deviation
- Stress measurement with DYNA Force® possible
- Infinitely restressable

## Main characteristics

Minimum Tendon Size	30 Wires
Maximum Tendon Size	84 Wires
Steel Grade of Wires	Y1670, Y1770
Wire Diameter	7 mm
Corrosion Protection	PE-Sheathing and Corrosion Protection Compound
Replacement possible	Yes
Restressing possible	Yes
Coupling possible	Yes
Possible Tendon Course	Sectional straight line with deviation, if applicable



## Anchorage

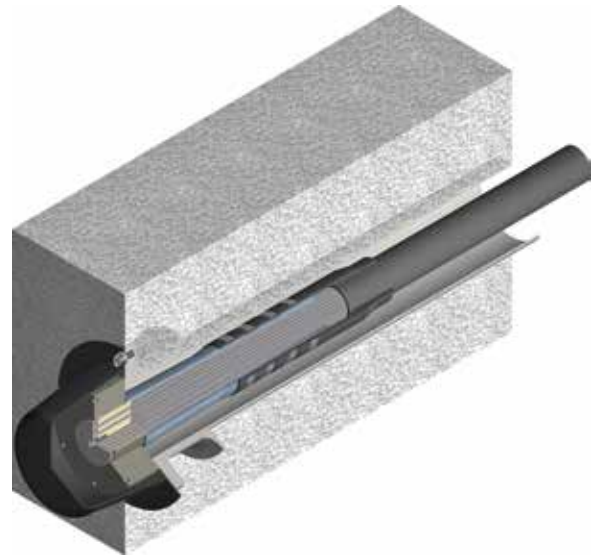
### MA anchorage

- 30-84 Wires
- Longitudinal Post-Tensioning of Bridges and Wind Power
- Minimum Concrete Compressive Strength from 33 N/mm<sup>2</sup> (Cube) at Time of Stressing
- ETA-07/0186

### Stressing anchor C



### Fixed anchor D

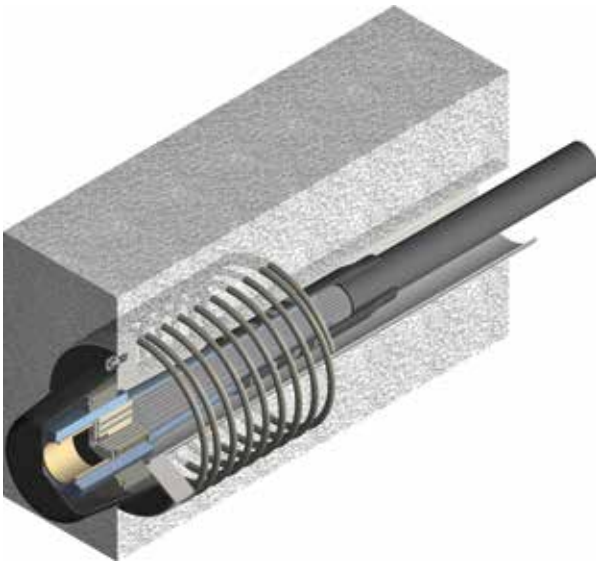




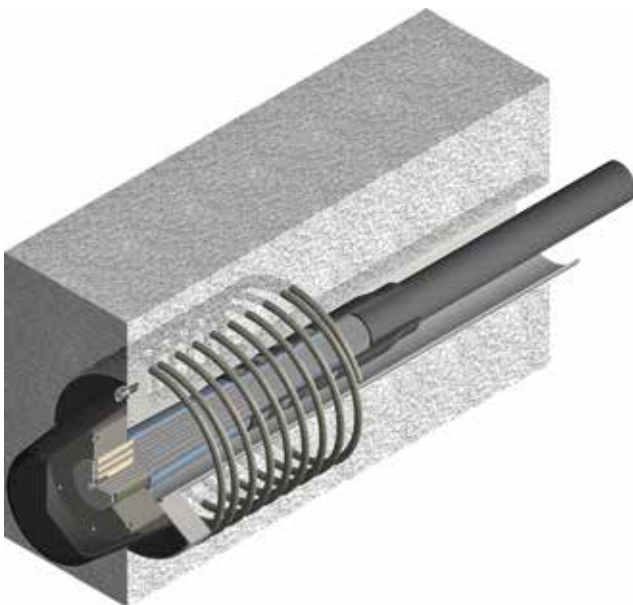
### Plate anchorage

- 30-84 Wires
- ETA-07/0186
- Minimum Concrete Compressive Strength from 33 N/mm<sup>2</sup> (Cube) at Time of Stressing
- Longitudinal Post-Tensioning of Bridges and Wind Power, Strengthening of Bridges for enhanced bending loading capacity

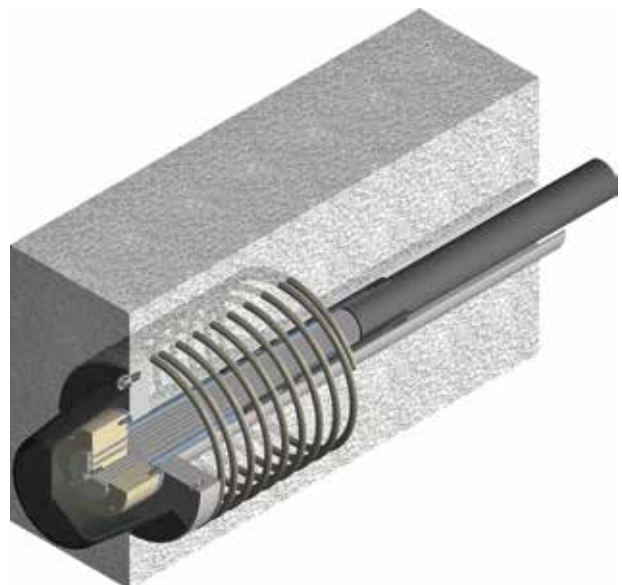
### Stressing anchor C



### Fixed anchor D



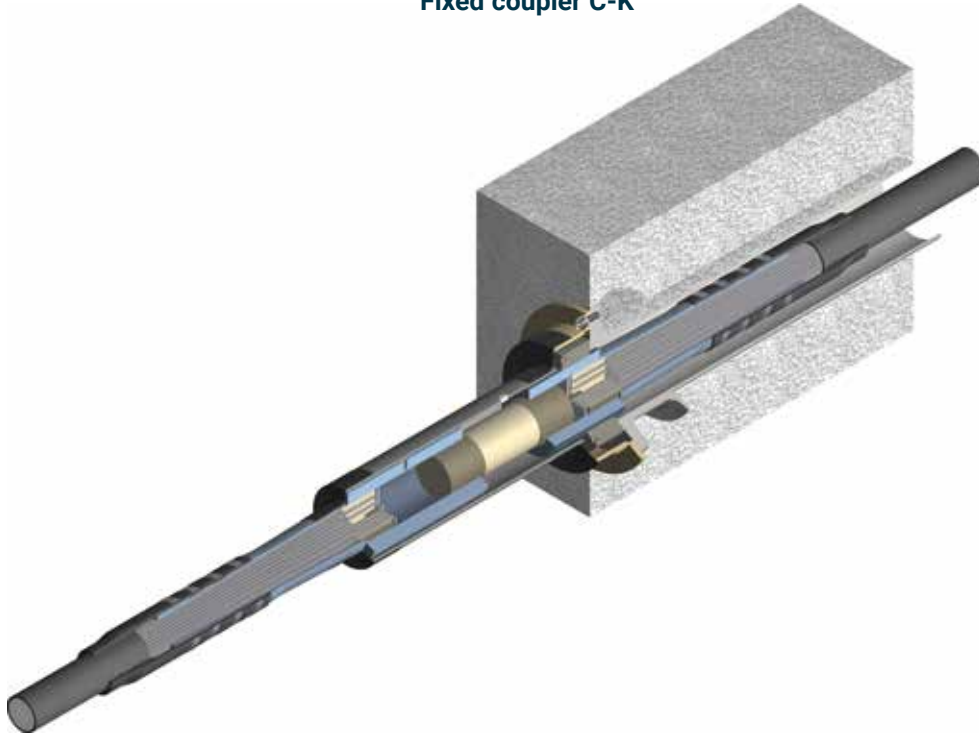
### Fixed anchor E (one-piece)



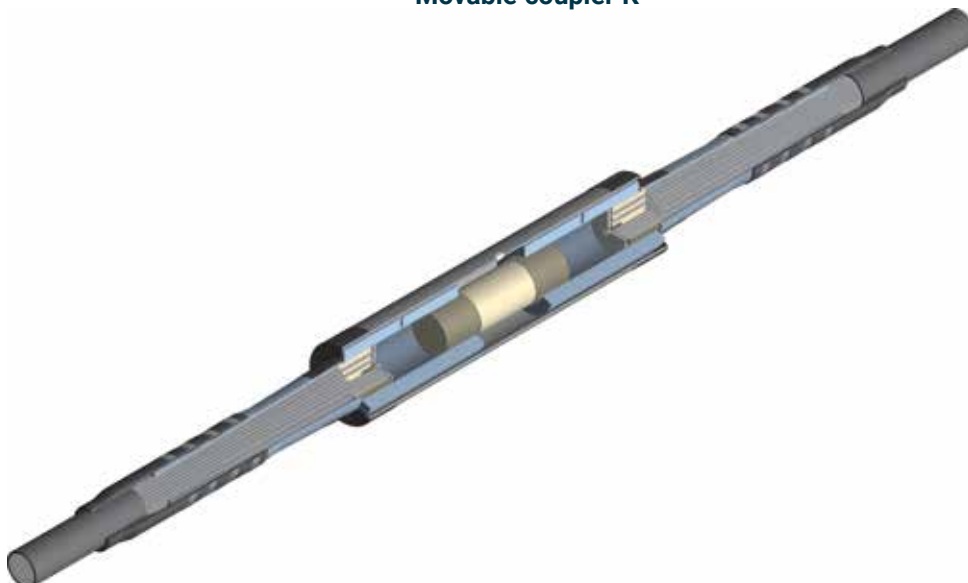
## Coupler

- 30-66 Wires, up to 84 Wires on request
- Longitudinal Post-Tensioning of Bridges and Wind Power, Strengthening of Bridges for enhanced bending loading capacity
- ETA-07/0186

**Fixed coupler C-K**



**Movable coupler K**

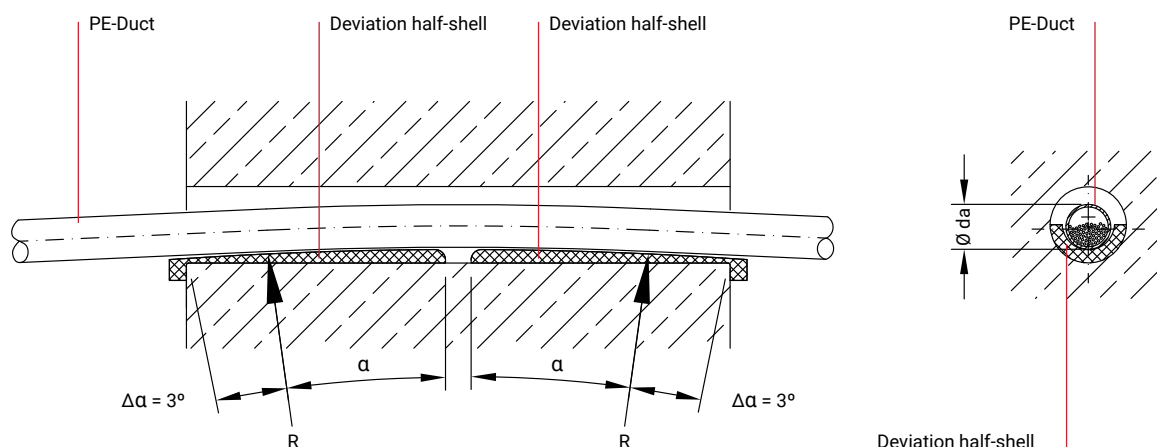


## Deviations

- Standard deviation setting up by means of deviation half-shells
- For special applications also possible as cast-in and bent ducts
- Bi-axial deviations are easily possible by using of deviation half-shells
- Intended deviation angle of up to 2 x 10° possible
- Deviation half-shells provide an allowance angle of 3° each direction for unintended deviations
- Minimum deviation radii depend on tendon size and steel grade, see table



### Tendon deviation with deviation half-shell



### Tendons with duct

Tendon Type SUSPA-Wire		EX-30	EX-36	EX-42	EX-48	EX-54	EX-60	EX-66	EX-72	EX-78	EX-84
—	—	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
PE-duct Type 1 <sup>1)</sup>	Ø da x s	75 x 4.3	75 x 4.3	90 x 5.1	90 x 5.1	90 x 5.1	90 x 5.1	90 x 5.1	90 x 5.1	90 x 5.1	90 x 5.1
Minimum deviation radius for wire grade St 1570/1670	R	2,700	2,700	2,700	2,700	2,700	2,900	3,200	3,500	3,800	4,00
Minimum deviation radius for wire grade St 1570/1770	R	2,500	2,500	2,500	2,500	2,800	3,100	3,400	3,700	4,000	4,300

<sup>1)</sup> Optimized duct diameter



# External Unbonded Bar Tendons

## Applications

- Strengthening of bridges to enhance shear load capacity
- Pier cap and base anchorage
- Stressing of deviators and anchor blocks for longitudinal strengthening

## Features

- Low slip Anchorages
- WS Bar Tendons for short Lengths < 2,5 m
- WR Bar Tendons for Lengths > 2,5 m
- DYNA Force® monitoring possible
- ETA-05/0123, Z-13.72-50123, resp.
- Restressable

## Main characteristics

Minimum Tendon Size	18 mm
Maximum Tendon Size	47 mm
Steel Grade of Bar	Y1050
Bar Types	WR/WS
Corrosion Protection	<ul style="list-style-type: none"> <li>▪ Heat Shrink Sleeve or DYNA Protect® Bar and PE-Duct</li> <li>▪ Grouting with corrosion protection wax acc. to EAD16, factory-controlled grouting with cementitious grout (DCP), grouting with cementitious grout after stressing</li> </ul>
Replacement possible	Yes
Restressing possible	Yes
Coupling possible	Yes
Possible Tendon Course	Mainly straight

## Anchorage

### System overview

Designation	Anchor Plate	WR Bar Types									WS Bar Types			
		18 WR	26 WR	32 WR	36 WR	40 WR	47 WR	57 WR	65 WR	75 WR	26 WS	32 WS	36 WS	40 WS
Unbonded and external bar tendon with solid square plate anchorage <b>without</b> additional reinforcement	2011	X	X	X	X	X	X	X	X	X	X	X	X	X
Unbonded and external bar tendon with solid square plate anchorage <b>with</b> additional reinforcement	2012	X	X	X	X	X	X				X	X	X	X

# Assembly and Installation

## Installation

### Site fabrication (for strand and bar)

- Ducts, strands or bars, anchorages and couplers are delivered to site on schedule
- Tread bars (WR) are usually delivered to site prefabricated to project-related lengths
- However, due to the continuous, robust coarse thread also cutting and coupling at any position of the tendon is possible

### Placing and fixing of the ducts

- Placement of the ducts on preinstalled chairs
- Alignment of the ducts to correct position and height
- Tying of the ducts for securing against lifting and displacement
- Installation of vents on high points
- Installation of vent tubes on high points and anchorages

### Coupling of metal sheet ducts

- One half of the coupler screwed onto the already placed duct
- Fixing and sealing by means of adhesive tape
- Placing next duct and screwing onto the coupler
- Fixing and sealing by means of adhesive tape

### Coupling of plastic ducts

- Connection of the duct section by attaching of the couplers
- Subsequent fixing and sealing



### Installation of the anchorages with corresponding additional reinforcement/helices

- Fabrication of the formwork with block-out for strands and bars as well as boreholes for threaded bars for installation of the anchorages
- Screwing-in of the treaded bars into the anchors, grout port to be covered for protection against pouring grout
- Anchor with threaded bars to be lead through boreholes in the formwork
- Threaded bars to be fixed with nuts from the outside
- With strands
  - Trumpet (transition tube to the duct) to be screwed onto the anchor
  - Helix and, if required, additional reinforcement threaded onto trumpet and anchor
  - Duct connected to the trumpet by means of a coupler, and fixed and sealed with tape
- With wires
  - Fitting of a retaining nut onto the stressing anchor
  - Scewing-in of the duct into the retaining nut and sealing by means of an adhesive tape
- Positioning and fixing of additional reinforcement and helix, if required
- With cast-in fixed anchors the process steps for fixing the formwork are omitted. In return adequate fixing of the reinforcement components is to be provided





## Installation of strand tendon couplers

- For installation of the fixed couplers in the first construction phase, the instructions for installation of the anchorages apply
- As soon as the tendon has been stressed and grouted in the first construction phase, the tendon can be connected in the second construction phase
- Installation of the ducts in the second construction phase, whereby a coupler trumpet with sleeve tube is to be provided for connection to the coupler
- Pushing in the strands from the stressing end of the second construction phase and connecting to the coupler
- Closing the coupler by pushing back the coupling trumpet
- In the second construction phase no stirrups or helical reinforcement is required in the coupler area
- For movable couplers, please refer to the installation instructions available on request

## Special features on Electrically-Isolated Tendons (EIT)

- Installation of the ducts onto prepared support rebars, if required plastic half-shells are placed underneath in deviation sections
- Particular importance is paid to the sealing of the duct couplers and the connections to the anchorages by means of heat shrink sleeves



## Pushing-in of the Prestressing steel

- Allow for appropriate space in the pushing area (no formwork elements in front of the anchorage opening, installation area for pusher and dispenser)
- Hoist for lifting of new strand coils required
- Pushing speed up to 400 m per minute
- On-site fabrication of bond or fixed anchorages
  - Only possible before concreting
  - Appropriate space to the peripheral formwork for mounting compression fittings
  - The top layer reinforcement may not be placed yet in the anchorage installation zone



### Prefabricated tendons

- Post-tensioning steel (strand or bar) is inserted into the duct in the factory to the highest quality standards
- The fixed anchors are installed
- Prefabricated tendons that are coupled to already installed tendons in the structure consist exclusively of strand bundles and ducts
- Strand tendons are delivered to the construction site on robust steel reels, ready for installation and just in time
- Uncoilers designed for the reels and tendon types are available in accordance with the highest safety standards
- Stressing anchors are supplied separately

### Installation of prefabricated strand tendons with pre-assembled anchorage

- Stirrups must be open to the top
- Rebars chairs must be installed. If there are multiple layers: Place the lowest layer of support rebars - place the lowest layer of tendons - place the next layer of rebar chairs - place the next layer of tendons, etc.
- Appropriate hoist for complete installation length including reel weight; hook height min. 5 m above top layer of tendons
- When using several hoists, sufficient load capacity of all hoists must be ensured at the handling point
- Uncoiling the tendon from the fixed anchor end
- Feeding the stressing end into the stressing anchors fixed to the formwork, connecting them with trumpet by means of a sleeve duct, fixing and sealing with adhesive tape

### Installation of stressing anchor and coupler

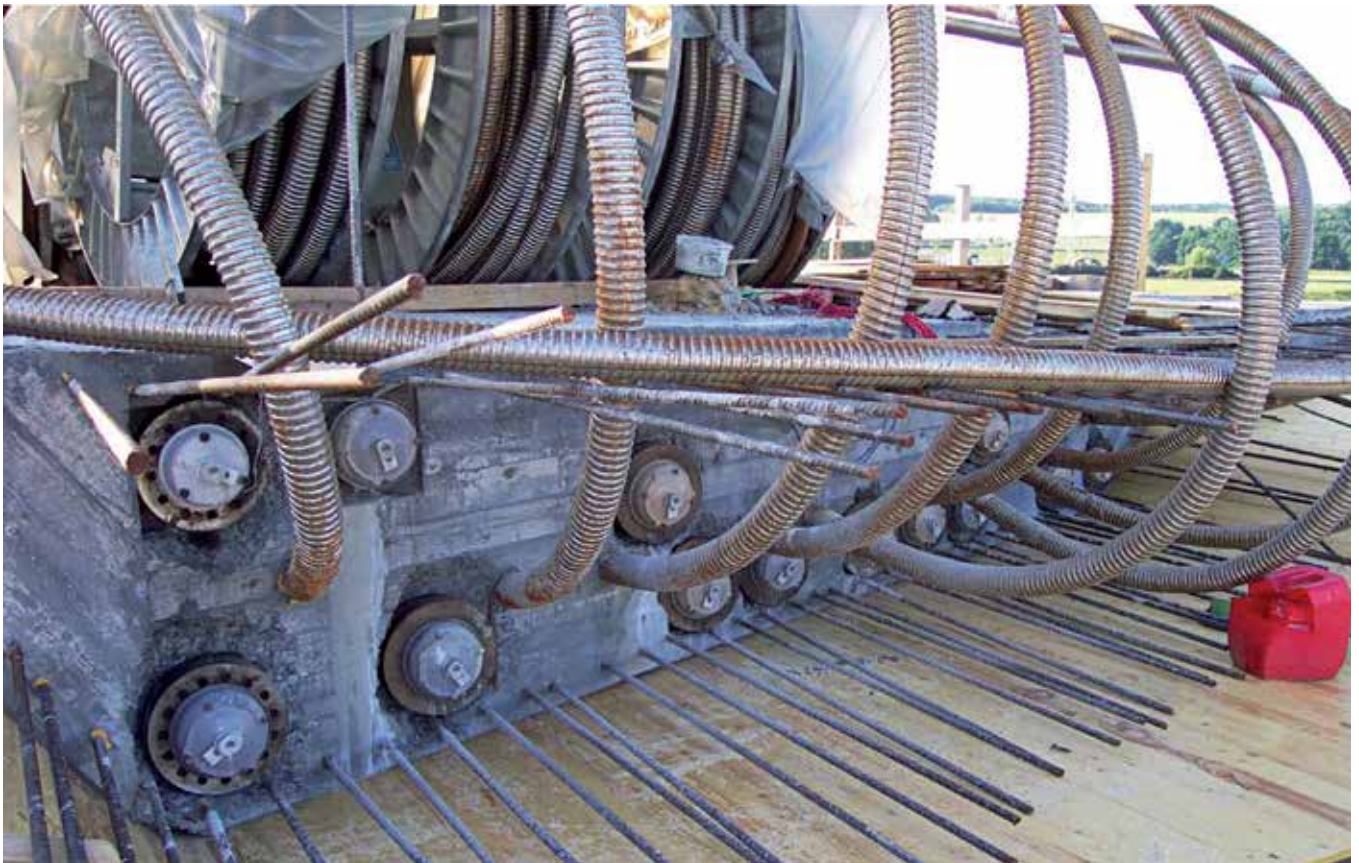
- Fixation of the stressing anchors to the formwork is carried out in the same way as with site production
- With Strands
  - Trumpet (transition tube to the duct) to be screwed onto the anchor
  - Helix and, if required, additional reinforcement threaded onto trumpet and anchor
- Positioning and fixing of additional reinforcement and helix, if required after threading of the prefabricated tendon
- The installation of the coupler is carried out in the same way as with site production





### Procedure for continuous tendons over several construction sections

- In some countries it is not allowed to couple all tendons at construction sections (100% coupling); this requires that a certain amount of the required tendons runs across the construction sections
- Install up to the end of the construction section to be concreted immediately, lay out the remaining tendon in the next construction section depending on the length and conditions, or place it on a reel
- After the concrete pour, relocate the tendon section that has not been concreted to the already concreted construction section
- Minimum deviation radii shall be met





### Fabrication of monostrand tendons – prefabrication or site production

- For **prefabricated monostrand tendons**, the individual monostrands are cut to length and bundled in the workshop according to plan, then the fixed anchor is installed
- Tendons are then delivered to site either on steel reels or in self-supporting coils or in straight line
- In case of **site fabricated monostrand tendons**, the anchorage components and monostrands (in coils) are delivered to site and installed on site as a complete assembly according to the installation manual

### Installation of prefabricated monostrand tendons with pre-assembled fixed anchors

- Pre-installation of the stressing anchors – this requires adequate space for placement and alignment of the strands during installation
- Placing the tendons on the tendon supports – these must be open at the top
- Feeding the single strands into the stressing anchor
- Alignment of the tendons - consider warping zone and bundling
- Fixing any one meter with plastic zip ties or any other fixings is not permitted



### Installation of anchorages with corresponding additional reinforcement

- Fabrication of the stressing pockets by means of formwork or pocket former (holes for threaded bars and opening for stressing head must be fabricated)
- Screw threaded bars into the stressing anchor, attach sealing ring
- Feed threaded bars through the bore holes in the formwork
- Fix the threaded bars with the nuts from the outside
- Install additional reinforcement (only required for closed stirrups), set in position and fix in place



## Factory production for internal unbonded bar tendons

- Unbonded bar tendons are prefabricated in the workshop and delivered to the construction site ready for installation
- The corrosion protection consists of a special, approved heat shrink sleeve or DYNA Protect® Bar and a PE-duct as mechanical protection
- Alternatively: design with protective PE pipe and factory-injected corrosion protection compound in the annular space
- Due to the prefabrication of the corrosion protection under controlled conditions and by trained factory personnel, the highest standards for the durability of the system are met
- Based on the existing corrosion protection during the installation of the bars, this system is particularly recommended for projects where already during construction stage a longer exposure time in the open formwork may be expected
- With an unbonded system, stressing force control or retensioning of the system is possible at any time

## Installation

- Alignment and fixation of the prefabricated bar tendon, as well as assembly of the anchor plates with attached tube and fastening to the formwork
  - Sealing of the tube to the tendon by means of adhesive tape or heat shrink sleeve
  - Filling of the annular space around the tube with corrosion protection compound
  - Temporary installation of the anchor nuts, as well as installation of the steel caps for protection until tensioning is carried out
  - When using movable coupler joints, both bar ends must be screwed halfway into the coupler and kept in position by means of special pressure-sensitive adhesive, a tapered cut of the bars or locknuts arranged on both sides.
- After positioning the duct sleeve with grout and vent ports, sealing to the PE protective tube is carried out. The annular space between the bar or coupler and the duct sleeve is grouted with cementitious grout or anti-corrosion compound after tensioning.

## External wire tendons for bridges

- External wire tendons of type Wire-EX are supplied completely prefabricated and corrosion-protected on reels to the construction site
- Pulling in complete prefabricated tendons offers the shortest possible installation times
- Special half shells allow a perfect adaptation of the tendon geometry to the actual structural conditions and can compensate for imperfections in the execution of the structure

## Fixing of penetration tubes prior to concreting of the bulkheads and placement of the deflection half shells

- Depending on the planned deflection situation (deflection angle, deflection radius and bulkhead thickness), DYWIDAG provides appropriate penetration tubes for the different tendon sizes
- Penetration tubes are straight and can therefore be placed accurately in the formwork; depending on the length, suitable stiffeners are available
- Immediately prior to the tendon installation, plastic half-shells are inserted into the penetration tubes from both sides of the cross girder. These half-shells can be moved in any circumferential direction and can thus be optimally aligned with the actual tendon geometry

## Pulling-in the tendons

- The tendons are pulled in using winches. The winch rope is passed through all deflection points and connected to the end of the reeled tendon
- The tendons are pulled into the superstructure through recesses in the abutment cross girder, or in the deck or floor slab, where the edges have to be lined adequately
- In boxed girders, the tendon is passed over pulleys located on the floor slab to prevent damage to the prefabricated tendons during installation



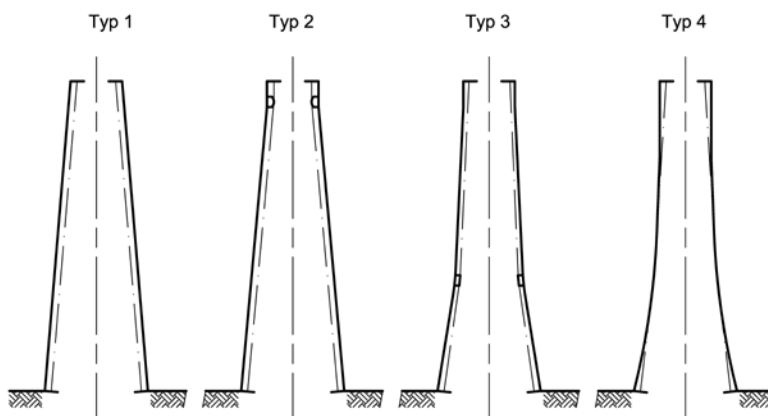


## External wire tendons for application in wind towers

- External post-tensioning system Wire-Ex with 30 to 84 wires, PE duct and pre-assembled stressing and fixed anchors
- Completely factory-prefabricated and corrosion-protected tendons
- Delivery of the tendons either on steel reels or coiled without reels
- Installation of tendons from tower crown or tower shaft possible
- Completely factory prefabricated tendons allow timesaving installation and stressing at the construction site
- The Wire-Ex post-tensioning method has been successfully employed in over 1,500 concrete and hybrid towers worldwide
- Retensioning, replacement and force monitoring of the tendons possible at any time

## Deviations

- Typical concrete towers have variable diameters, resulting in changes in inclination of the tower wall
  - See Type 1-4
- External tendons located close to the tower wall usually need therefore to be deviated
- The robust sheathing allows various deviation situations where corrosion protection durability has been proven by extensive testing
- Small deviations (type 4) are obtained by direct contact of the tendons with the tower wall
- Larger deviations (greater than  $1^\circ$ , cf. type 2 or type 3) are achieved by arranging deviation half-shells
- The deviations of tower types 2-4 may also be combined



### Installation from the tower crown

- Insert tendons supplied on reels into the uncoiler. Self-supported tendon coils are placed in a hinged reel beforehand
- The uncoiler is lifted by crane approx. 5 m above the tower crown. From there, the tendon is uncoiled. In this process, the basic body of the stressing anchor is first threaded through the recess in the upper anchor plate and lowered to the base slab or steel structure
- Prior to completion of the insertion work, the tensioning sleeve is turned onto the basic body and the tensioning spindle is screwed into the internal thread of the tensioning sleeve



### Installation from the tower shaft

- Installation of the tendons requires no crane and is therefore possible independent of the wind speed
- The tendon is pulled upwards by means of an electric hoist
- The fixed anchor is fixed to the top ring by screwing the bearing nut onto the basic body
- Installation can even be executed after the electrical equipment has been installed in the tower, so offering maximum flexibility
- The insertion process is completed by turning the tensioning sleeve onto the basic body and screwing the tensioning spindle into the internal thread of the tensioning sleeve



## Factory production for external bar tendons

- External bar tendons are prefabricated in the factory and delivered to the construction site ready for installation
- Corrosion protection consists of a special, tested heat shrink sleeve or DYNA Protect® Bar and a PE duct as mechanical protection
- Alternatively: version with PE duct protective and annular space injected in the factory with corrosion protection compound
- External bar tendons can either be freely installed in a recess or drill channel or arranged in or along the structure
- Prefabrication of the corrosion protection under controlled conditions and by trained staff in the factory means that the highest standards of system durability are met
- Additional grouting of the tendon (e.g. wax grouting) on site can be avoided. This significantly increases the installation speed for time-sensitive projects (e.g. precast structures)
- With an external placement of the prefabricated tendon, prestressing force monitoring, restressing and, under certain conditions, removal of the system is possible at any time

## Installation

- Insertion of the external bar tendon into the recess channel
- Threading and alignment of the anchor plate with tube. Sealing between the tube and PE protective duct is provided by means of a gasket insertion in the tube. It is recommended to apply a high strength leveling layer for a solid load transfer in case of an uneven bearing surface.
- Temporary installation of the anchoring nuts, as well as installation of the steel protective caps for protection until stressing
- When using movable couplers, both bar ends must be screwed halfway into the coupler sleeve and locked in position by means of special adhesive, a bevel cut of the bars or locknuts arranged on both sides. After positioning the sleeve duct with grout and vent ports, sealing to the PE protective duct is conducted. The annular space between the bar or coupler sleeve and the sleeve duct is filled with cementitious grout or anti-corrosion compound after stressing.





## Stressing

### Post-tensioning of strand tendons (bonded or unbonded)

#### Threading of the jack

To install the press, thread two mutually twisted combs in the wedge plate area and pull them back to the strand end

- Slide the bullets onto the strand ends
- Slide on compression plate
  - Place jack onto the strand
  - Connect hydraulic hoses between pump and jack
    - Sufficient space required on the scaffold
    - Sufficiently dimensioned hoist required
- The stressing niche must be fabricated in accordance with the specifications – any interfering rebar or concrete parts shall be avoided



#### Stressing according to stressing instruction and anchoring

- Applied by hydraulic system and, depending on the elongation, in several steps
- The area behind the jack shall strictly not be accessed during the stressing operation for safety reasons
- Wedges are retracted to the jack plate during stressing; when released, they slide into the wedge seat and thus anchor the strands in the wedge plate



#### Record of stressing forces

The stressing force is measured by means of a manometer and manual reading of the elongation - this is recorded in the stressing record





### Stressing of wire tendons for external application

- The stressing force is applied by means of hydraulic jacks, depending on the elongation optionally in several steps, and in accordance with the stressing record
- Prestressing can be carried out even under difficult boundary conditions by using lightweight and compact hollow piston jacks and corresponding stressing equipment
- For stressing, the tensioning spindle is screwed into the tensioning sleeve of the stressing anchor. Then bearing nut and the buttress nuts for the stressing operation are mounted over the spindle
- The stressing jack is sitting on the anchor plate by means of a support frame fitted with openings
- For tensioning, the stressing jack engages with the tensioning spindle
- During the stressing operation, the stressing accessories are turned through the openings of the support frame
- The force applied during stressing is continuously measured by means of a manometer and documented in the stressing record together with the measured elongation
- At the end of the stressing operation, the tendon is seated with the bearing nut at the stressing force specified in the stressing record
- For safety reasons the area behind the jack shall be kept clear, not be accessed, respectively





## Stressing of bar tendons

### Mounting of the jack

- After temporary extension of the bars by means of a tensioning spindle, the tensioning jacks specially developed for the bar tensioning process are placed on the bar to be tensioned with a built-in ratchet. After screwing on the high-strength stressing nut behind the jack and connecting the hydraulic pump, the stressing operation can start
- Stressing is executed on the basis of a checked stressing instruction specifying the prestressing force, the applied hydraulic pressure, the expected elongation of the tendon and the stressing sequence
- After application of the specified hydraulic pressure, the anchor nut is set onto the anchor plate by means of the ratchet which is an integrated part of the stressing jack, thus anchoring the prestressing force
- After releasing the hydraulic pressure, the stressing jack can be removed again together with the stressing spindle and stressing nut. Thereafter, the bar projection behind the nut can be compared with the projection before stressing. The determined elongation path is then recorded in the stressing record
- In case of prestressing work in confined spaces, special compact or project-specific prestressing jacks can be provided after consultation with DYWIDAG



### Stressing according to stressing instruction

The stressing jack is sitting on the anchor plate by means of a support frame fitted with openings

### Record of stressing forces

The stressing force is measured by means of a manometer and manual reading of the elongation – this is recorded in the stressing record



## Corrosion protection

### Grouting of post-tensioned strand and bar tendons with cementitious grout

- Corrosion protection of tendons, anchorages and couplers is provided by cementitious grout in accordance with EN 447
- The mixture of the grout, the mixing process and the grouting process are subject to the highest structural engineering standards
- The grouting process is solely carried out and documented by trained and certified DYWIDAG personnel

### Installation of the grout caps/ accessories

- Screw the grout caps thoroughly onto the wedge plates
- Screw vent tubes into the grout ports of the stressing anchors and open the valves





## Grouting preparation

- Patency test: testing the patency of the section to be grouted by means of compressed air
- In case a tendon is not continuous, the duct must be drilled to accommodate a new vent port
- Testing of external temperature and temperature of the structure: Measured temperatures may not exceed minimum and maximum values

## Suitability test of the grout

- Immersion tests according to EN 445 (1996):
  - The cylinder is filled with about 1.9 liters of grout to about 26 cm below the rim, so that the plunger is just fully immersed when inserted, when its stop on the guiding rod rests on the spacer placed on top of the tube
  - The spacer is removed, the immersion body sinks to the stop on the tube
  - The immersion time is measured
- Funnel test according to EN 445 (2005):
  - 5 l of the grout shall be slowly poured into the funnel through the sieve to avoid the formation of air bubbles in the grout
  - The lower funnel outlet is now opened and the stopwatch is started at the same time
- Tests are carried out with grout immediately after mixing from the hopper and after 30min
- Volume change:
  - In order to carry out a sedimentation test to determine the volume change, samples must be filled into sealable 1 kg cans of approximately 120 mm height and of approximately 99 mm internal diameter
  - After filling the grout into the cans, the distance of the grout surface from the can rim is measured by means of a depth gauge and a stop plate
- Cans are sealed and stored protected from vibration and thermal radiation
- After 24 hours, a control measurement is taken between the solid grout surface and the can rim. The difference of the mean values between zero and control measurement in mm corresponds at 100 mm filling height to the change in volume in vol. %
- The change in volume of the cans may not exceed 2%; the objective is to obtain an expansion

## Grouting operation

- Set the water quantity on the grout mixer and fill it into the mixing drum
- When using grouting agents, these are added together with the cement according to the specified recipe
- When using grout cements with integrated additives, these are added in accordance with the application notes
- Mixing time is typically 120 s
- Ready-mixed grout is pumped into the hopper of the mixer
- Mixer hose is plugged to the tendon to be grouted
- Dead end vents as well as any intermediate vents must be open
- Grout is pumped in until the grout pours out at the outlet free of air bubbles and in due consistence



- Once the discharged grout meets the specification, the tendon is closed at the outlet, then increased pressure is built up by the mixer and the tendon is closed at the grout port

## DOCUMENTATION

- Results of the suitability test are recorded in test records
- Documentation of the grouting sequence with details of the grouting operations



### Corrosion protection in the anchorage zones of unbonded tendons / monostrand anchorages

- Cutting off the strand protrusions with an angle grinder or cutting device
- Attaching PE caps filled with corrosion protection compound to the strand ends
- Placing the sealing gasket and keeper plate, then screwing them onto the cast anchor
- Filling the anchorage pocket with concrete



### Corrosion protection in the anchorage zones of external wire tendons

- After installation or after stressing, the fully prefabricated fixed anchor and the on-site installed stressing anchor shall be protected against corrosion
- Special greases or grease-soaked fabrics are wrapped around the external thread of the bearing nut and tensioning sleeve
- Finally, the entire anchorage zone is covered by a PE cap

### Wrapping the visible anchor parts with corrosion protection tape

- Unscrew the protective transport caps from the basic body
- Screwing the tensioning sleeve onto the thread of the basic body that has already been coated during factory production
- Coating the end face of the tensioning sleeve on the tendon side and the upper half of the thread with Vaseline
- Coating the end face of the anchor plate side of the bearing nut with Vaseline
- Cleaning the entire anchor body of any debris and fully wrapping (covering) the entire anchor with anti-corrosion tape



### Installation of the anchor caps

- Inserting/attaching the PE supporting/protection pot provided with anti-corrosion compound into/onto the tensioning sleeve
- Wrapping Denso sealing tape around the external thread of the tensioning sleeve and the bearing nut
- Fitting the anchor cap onto the anchor plate and fixing it by means of screws backed with DUBO locking
- Covering the screws with the PE-cap
- Fitting the anchor cap onto the anchor body and fixing by means of threaded bars and nuts



## Wax injection of external strand tendons

- Wax injection of external strand tendons is performed on site due to design requirements
- Corrosion protection waxes for tendons are heated to 100-110 °C for application
- Injection from an anchor or, in the case of very long tendons, from a low point along the free length
- Positioning of vents in sufficient number and preparation of an injection manual for intended sequence
- Sealing at anchors, caps, grout ports and vents
- Perform pressure test on duct to verify tightness prior to injection



- All injection ports and vents on tendons shall be attended by personnel. All personnel shall be briefed prior to injection and shall be in steady contact via radios
- Preheat and maintain adequate quantity of wax for injection. Tank (car) and pump are usually located on the bridge so that the hot wax is led from above via hoses into the superstructure and to the tendons.
- During injection, the pressure, temperature and injected quantity are monitored at all times. In addition, the progressive filling in the tendon can be controlled by using a thermal imaging camera
- When the injected wax reaches the vents, they are closed after overflow of 3-5 l of wax
- After complete filling of the tendon and closing of all vents, the injection pressure is maintained for a short time. After completion of injection, the vents and caps are permanently sealed





# Equipment

## Installation devices

### Strand cage

Strand cages are used for uncoiling the strand, which can be universally used for both left and right wound strand. Strand coils of up to 4 tons can be used. Due to various setting options, the

strand cages can be perfectly adapted to a wide range of coil sizes. The robust design as well as integrated transport aids (forklift receptacle and transport lugs) are just a few features reflecting

the perfect optimization of the strand cages for construction site application.

### Pusher

By means of the pusher, the strand can be pushed into the duct at up to 12.2 m/s. The highest priority is also given to a robust design suitable for construction sites for these devices.

The pushers are hydraulically driven. The feeding speed is continuously adjustable. The maximum pushing force is 3.9 kN.



### Uncoiler/ reels

Reels are the easiest way to install prefabricated tendons. Due to their rather small dimensions and simple design, the devices have a very low dead weight. Neither electric

nor hydraulic drives are required. The braking effect is generated mechanically via air pressure using compressed air cylinders. Uncoilers, on the other hand, are much more complex

and elaborately designed. Unlike the reels, an electric drive makes it possible to wind up tendons as well. Both speed and direction can be controlled by remote control.



## Stressing jacks

Due to their robust design, DYWIDAG stressing jacks have proven their reliability in rough construction site conditions for decades.

In our in-house workshop, the devices are assembled, regularly serviced, repaired as required and calibrated.

## Strand tendons

DYWIDAG stressing jacks are outstanding for their robust design made of hard-chromium plated alloy steel and/or aluminum alloys and cover a wide range of applications.

Due to rapidly exchangeable adaptations the stressing jacks can be applied to a wide range of tendon types. A standard automatic gripping device allows easy handling on the construction site.

Likewise, it is optionally possible to attach a power seating device for minimizing wedge slip. With special adaptations, the stressing jacks can also be used for destressing tendons.

## Bar tendons

DYWIDAG bar tensioning jacks are designed for easy handling to facilitate and subsequently speed up the tensioning operation. The jacks are coupled via tensioning spindles to the projecting end of the bar

tendons behind the nut and are fixed by a tensioning nut. By means of an integrated wrench sleeve with hand ratchet, the nut is force-tightened after the tensioning operation. Thus, slippage is reduced to a minimum. For overhead

application or in particularly confined spaces, tensioning jacks with worm-gear cylinders are available achieving a high tensioning force despite very low weight.

## Wire tendons

Carbon fiber reinforced hollow rams provide a good alternative to conventional steel or aluminum tensioning jacks.

Direct comparison reveals a weight saving of at least 60%, allowing easier handling during tensioning operations. The lightweight and slim design allows work to be carried out in confined spaces.

Despite the lightweight design, CFRP hollow rams are still robust and durable.

## Hydraulic pumps

Suitably optimized hydraulic pumps are available for the tensioning jacks. This allows fast and safe operation. The hydraulic pumps have up to three fittings, depending on the type of jack used, for gripping, power seating and runback.

Oil flow rates of up to 22 l/min can be achieved. If required, hydraulic pumps are available with cable remote control, which makes it easy to choose a safe and optimal location for the pump, even at some distance from the stressing position.

Optionally, cooling units for the oil can be set in-between to ensure the perfect operation temperature of the oil even in case of permanent use or very high outside temperatures.

## Grout mixer with pump

The grouting operation is based on a highly plasticized and thixotropic grout. For this purpose, durable grouting equipment has been developed. Advanced methods such as pressure grouting, post-grouting and vacuum grouting are the result of many years of continuous development.

### Swibo

The SWIBO grouting and mixing unit has been approved by the German approval body. Besides the good mixing and grouting properties, the focus during the development was also on the transport properties. Hence, every mixing and grouting unit of this type is fitted on a trailer chassis and is licensed according to the road traffic regulations.

### MP-Series

The MP series is designed to be compact while maintaining high performance. The maximum pumping capacity is 4,000 l/h (MP 4000-2) with a mixing drum capacity of 100 l.



Equipment



## Vacuum grouting devices

Vacuum grouting devices are used for the repair of tendons. By using the corresponding volume measuring system, the first step is to determine the volume of the defective sections. Subsequently, grouting is carried out. Grout is injected into the void and the amount of injected grout is measured. Finally, the grout volume is compared with the previously measured void volume to check whether the voids have been completely filled.



# Services

## Engineering service (consulting, detailing and design)

In all design stages of a concrete structure, DYWIDAG offers a comprehensive range of engineering services:

- Identification of suitable stressing systems for preliminary and construction design
- Optimization of anchorage zones for preliminary and construction design
- Supply of CAD drawing blocks for anchorage areas
- Supply of CAD drawing blocks for deviation zones of external tendons
- Preparation of assembly drawings
- Preparation of stressing records

In addition, we offer further planning services, particularly for building construction:

- Redesign of flat slabs originally designed as reinforced concrete slabs, to prestressed concrete slab systems with optimized slab thicknesses or larger spans between columns.

- Design of flat slabs in accordance with EN 1992-1-1 and the applicable national annexes
- Preparation of the associated formwork and reinforcement drawings (incl. reinforcement data)
- Preparation of stressing records

## Production and supply of tendons

- Manufacture of project-specific tendons (bonded strand tendons up to 150 m in length, bar tendons and monostrand tendons) with preassembled fixed anchor (as an alternative to the fixed anchor, a coupler can also be preassembled in order to extend tendons of the subsequent construction section).
- Delivery to the construction site on schedule
  - On reels for direct use in uncoilers provided by DYWIDAG
  - Self-supporting with the option of inserting them into temporary reels at the construction site and then hooking them into uncoilers
- Manufacture of project-specific external tendons (type Wire-EX) with factory-finished corrosion protection and anchorages on both ends

## Complete installation

### Bonded tendons

- Placement of ducts with professional fixing, installation of the anchorages and connection of the anchorages to the ducts
- Installation of prefabricated tendons with professional fixation, installation of the anchorages and connection of the anchorages on the stressing end to the ducts
- In the case of field fabricated tendons, pushing prestressing steel strands into the ducts
- Stressing operation in accordance with stressing records in as many stages as required, with professional documentation
- Grouting of the tendons with cementitious grout with professional documentation

### Internal unbonded tendons

- Installation of prefabricated tendons with professional fixing, installation of the anchorages and corrosion-resistant connection of the anchorages on the stressing end
- Stressing operation in accordance with stressing records in as many stages as required, with professional documentation
- Corrosion protection of the anchorages with professional documentation

### External tendons

- Execution of surveying and core drilling operations on the existing structure
- Pulling-in or feeding-in the tendons
- Professional installation of deflection half shells in deviation areas
- Stressing operation in accordance with stressing records in as many stages as required, with professional documentation
- Corrosion protection of the anchorages with professional documentation

## Supervision of stressing operations

Some work may also be carried out by the contractor after instruction by and under supervision of DYWIDAG:

- Placement of ducts and installation of anchorages
- Placement of monostrand tendons and installation of anchorages
- All stressing operations and corrosion protection work (incl. grouting with cement grout) are carried out exclusively by specialist personnel from DYWIDAG or specialist companies qualified by DYWIDAG

## Monitoring

- Preparation of monitoring solutions in cooperation with the structural engineer
- Supply and installation of load cells or elastomagnetic sensors for force measurement (DYNA Force®)
- Supply and installation of standard sensors (e.g. for temperature, strain, acceleration, inclination, etc.)
- Electrical connection of all sensors by local certified partners
- Integration of all sensors into a global monitoring system
- Data logging and data analysis
- Maintenance and servicing of monitoring systems during the operation period

## Survey of tendons in existing structures

### Bonded tendons

- Evaluation of the grouting condition
- Endoscopy of tendons
- Vacuum grouting of insufficiently grouted tendons

### Internal unbonded tendons

- Determination of the stressing forces by means of lift-off tests
- Restressing

### External tendons

- Visual inspection
- Condition inspection by robot-assisted non-destructive MI test
- Determination of the stressing forces by means of lift-off tests
- Determination of the stressing forces by means of vibration measurement
- Restressing of tendons
- Replacement of tendons
- Retrofitting of elastomagnetic sensors

## Tendon replacement / strengthening of prestressed concrete structures

### Bonded tendons

- Supply, installation and stressing of DYWIDAG bar tendons, e.g. for anchor and deviator blocks for retrofitted external post-tensioning

### Internal unbonded tendons

- Placement of additional unbonded DYWIDAG bar tendons (tendons with bond anchor)

### External tendons

- Strengthening of bridge structures against shear stress using external bar tendons from DYWIDAG
- Supply, installation and stressing of external wire and strand tendons for bridge strengthening
- Installation of external monostrand tendons for retrofitting of tank structures

## Tendons for temporary applications

### External tendons

- DYWIDAG bar tendons for pier head strengthening and bearing replacement
- Tendons for temporary support of high loads

## Training and certification of stressing personnel

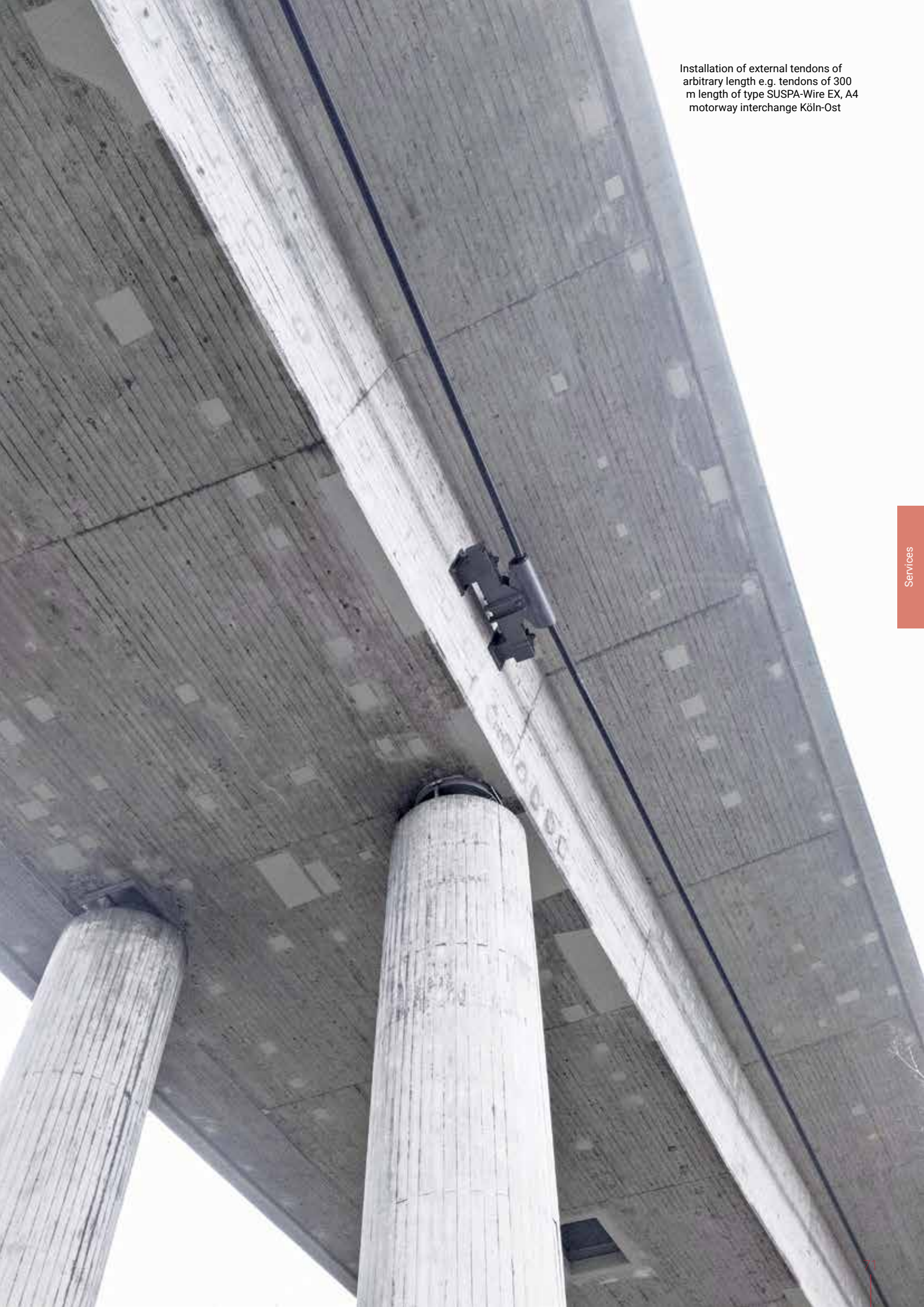
Professional installation of the tendons and qualified execution of the post-tensioning and corrosion protection work are essential requirements for the high technical quality, reliability and durability of DYWIDAG and SUSPA Post-Tensioning Systems. Therefore, all such work may only be carried out by DYWIDAG specialist personnel or by specialist companies qualified by DYWIDAG.

Both DYWIDAG's specialist personnel and those of the specialist companies must receive initial training or have sufficient experience for each stressing method (bar, wire, strand) separately, depending on the application. Furthermore, regular training courses are held. Special attention is paid to health and safety at work and the use of hydraulic equipment.

The training program consists of theoretical and practical parts. The achieved qualifications and skills have to be proven. The qualification of each individual specialist is certified after passing the examination.



Installation of external tendons of arbitrary length e.g. tendons of 300 m length of type SUSPA-Wire EX, A4 motorway interchange Köln-Ost



# DYWIDAG products and services



## Structural health monitoring

Automated and manual monitoring including survey. Supply and installation of automated and manual monitoring and survey systems, this data can also be viewed on our infrastructure intelligence platform.



## Concrete technologies

Permanent formwork systems and slab edge forms, form ties, reinforcement technologies - stop ends and starter packs, concrete accessories, sealing and chemical solutions.



## Geotechnical

Specialist supplier of ground engineering products including ground anchors, tension piles, soil nails and mesh, rock bolts, smart anchors, marine tie bars and associated accessories.



## Infrastructure Intelligence

Data acquisition platform, automated alarms and alerts, bespoke tailored system to suit your project.



## Repair and refurbishment

Testing and repair of existing ground anchors, refurbishment of post-tensioning systems to existing structures, rope access and wrapping of stay cables.



## Robotics, inspection and maintenance

Design and installation of stay cable systems plus the monitoring and inspection using robotic inspection methods.



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