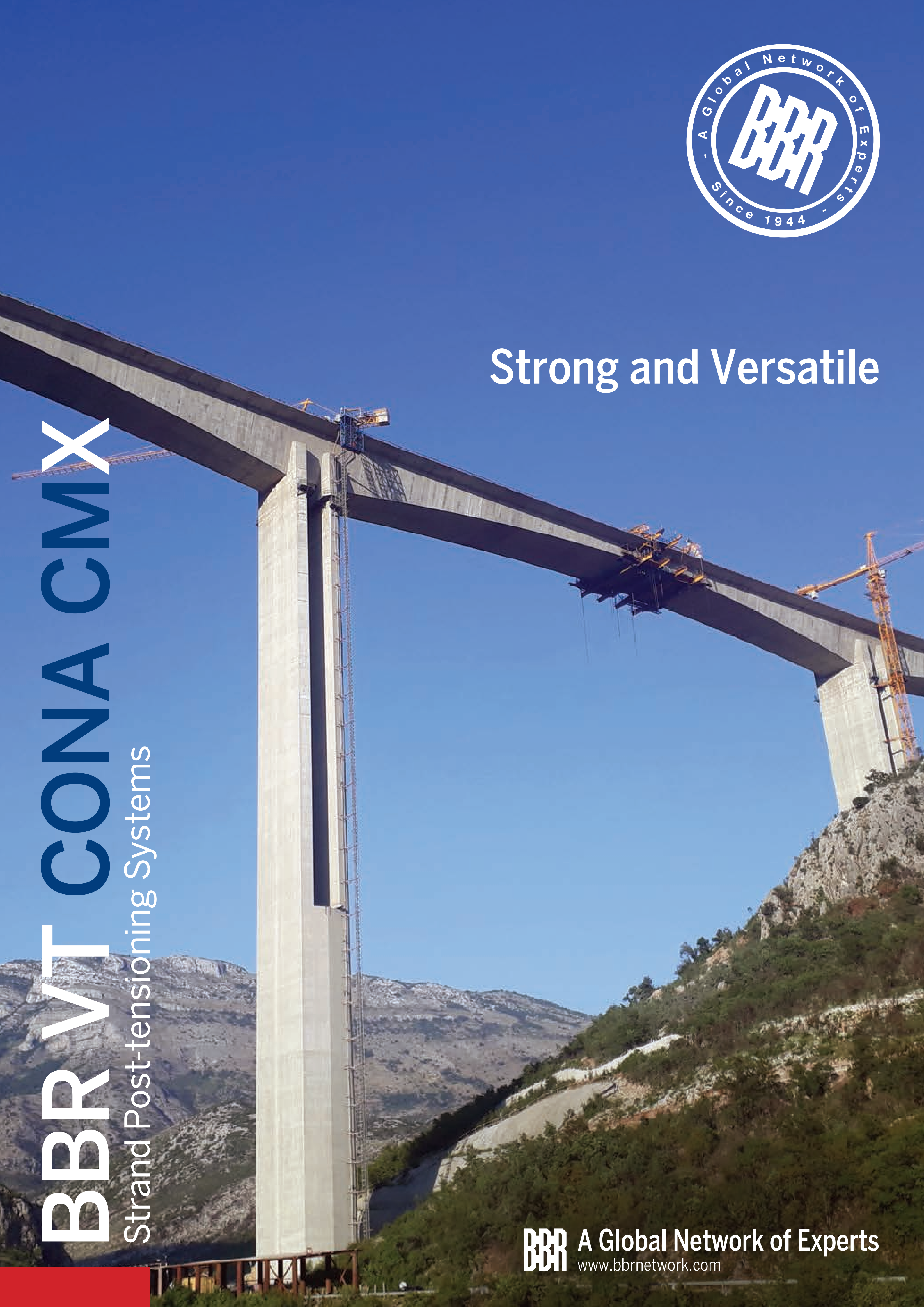


BBR VT CONA CMX

Strand Post-tensioning Systems

Strong and Versatile

A Global Network of Experts
www.bbrnetwork.com

A Global Network of Experts

www.bbrnetwork.com

The BBR Network is recognized as the leading group of specialized engineering contractors in the field of post-tensioning, stay cable and related construction engineering. The innovation and technical excellence, brought together in 1944 by its three Swiss founders – Antonio Brandestini, Max Birkenmaier and Mirko Robin Ros – continues, more than 75 years later, in that same ethos and enterprising style.
From its Technical Headquarters and Business Development Centre in Switzerland, the BBR Network reaches out around the globe and has at its disposal some of the most talented engineers and technicians, as well as the very latest internationally approved technology.

THE GLOBAL BBR NETWORK

Within the Global BBR Network, established traditions and strong local roots are combined with the latest thinking and leading edge technology. BBR grants each local BBR Network Member access to the latest technical knowledge and resources – and facilitates the exchange of information on a broad scale and within international partnering alliances. Such global alliances and co-operations create local competitive advantages in dealing with, for example, efficient tendering, availability of specialists and specialized equipment or transfer of technical know-how.

ACTIVITIES OF THE NETWORK

All BBR Network Members are well-respected within their local business communities and have built strong connections in their respective regions. They are all structured differently to suit the local market and offer a variety of construction services, in addition to the traditional core business of post-tensioning.

BBR TECHNOLOGIES & BRANDS

BBR technologies have been applied to a vast array of different structures – such as bridges, buildings, cryogenic LNG tanks, dams, marine structures, nuclear power stations, retaining walls, tanks, silos, towers, tunnels, wastewater treatment plants, water reservoirs and wind farms. The BBR™ brands and trademarks – CONA®, BBRV®, HiAm®, HiEx, DINA®, SWIF®, BBR E-Trace and CONNÆCT® – are recognized worldwide.
The BBR Network has a track record of excellence and innovative approaches – with thousands of structures built using BBR technologies. While BBR's history goes back over 75 years, the BBR Network is focused on constructing the future – with professionalism, innovation and the very latest technology.

BBR VT International Ltd is the Technical Headquarters and Business Development Centre of the BBR Network located in Switzerland. The shareholders of BBR VT International Ltd are BBR Holding Ltd (Switzerland), a subsidiary of the Tectus Group (Switzerland) and KB Spennteknikk AS (Norway), a subsidiary of the KB Group (Norway).

A solution for every challenge

The BBR VT CONA CMX® range of post-tensioning offers a solution for every type of construction engineering challenge – from high level motorway viaducts, dams and nuclear power generation to sporting stadiums, high rise towers and super flat ground slabs for major distribution warehouses and many more applications.

BBR has over 75 years of expertise and experience of innovating to satisfy customer needs. The company was founded to create new, smarter ways to build – and, in fact, has never stopped refining and optimizing its construction engineering technology to suit changing market requirements.

Our CONA CMX technology has been thoroughly tested by independent laboratories and bears the CE mark, indicating that it has a European Technical Assessment. The quality process is continued by the BBR Network Members who are all trained and experienced in the selection and installation of the most suitable system.

International post-tensioning certification

Post-tensioning kits for use in the European Community are required to have a European Technical Assessment, which is based on a set of defined testing procedures that must be fulfilled. Once the post-tensioning systems are placed on the market, they are subjected to factory production control and independent and continuous surveillance. Post-tensioning kits must be installed by trained Post-Tensioning Specialist Companies to ensure professional and system-conforming installation.

Legal basis

With the introduction of the Eurocode and according to the European Construction Products Directive – (CPD), construction products used in the European Community (EC) are required to carry "CE marking" – a mandatory conformity mark. CE stands for Conformité Européenne – "European conformity". Post-tensioning kits can only carry CE marking if a **European Technical Assessment (ETA)** has been obtained from a nominated Approval Body and after an EC – Certificate of Conformity has been obtained from an eligible Approved / Notified Body. The official guidance document giving the requirements for obtaining an ETA was published in 2002 under ETAG 013 and later updated by EAD16* "European Assessment Document of Post-tensioning Kits for Prestressing of Structures" which details a set of testing procedures which have to be fulfilled.

The European Organization for Technical Assessments (EOTA) comprises the Approval Bodies nominated to issue ETA after the testing provisions stipulated in EAD16 have been fulfilled and after European consultation has been successfully completed. European consultation involves circulation of the technical documentation of the post-tensioning kit, with a summary of the tests performed on the system, to all nominated Approval Bodies within the European Union. An ETA is issued for a proprietary post-tensioning kit to the ETA Holder with a designated Kit Manufacturing Plant of the components. As of 2008, use of CE marked post-tensioning systems has been mandatory throughout the whole of Europe and use of the Eurocode is mandatory from 2010 onwards. The provisions made for European approved post-tensioning kits are based on an assumed intended working life of the post-tensioning system of 100 years. The EC – Certificate of Conformity attests that the manufacturing of the individual components is subject to the continuous surveillance of an independent authority (Approved / Notified Body), which checks that the manufactured components comply with the components outlined in the particular ETA.

** ETAG 013 has been extended to EAD16, which is also fullfilled by BBR products.*

Typical testing provisions

EAD16 “European Assessment Document of Post-Tensioning Kits for Prestressing of Structures” details the full scale tests the post-tensioning kit has to undergo. The basic testing provisions include the following:

Static tensile tests for each anchorage and coupler type – A complete tendon is first stressed by means of standard stressing equipment to 80% of the characteristic ultimate tensile strength of the tendon (UTS). The load of 80% UTS is then maintained for a duration of two hours, after which the tendon is stressed – by means of an external testing machine – to failure. An efficiency of at least 95% of the actual ultimate tensile strength of the tendon and 2% elongation must be achieved.

Fatigue tests for each anchorage and coupler type – The acceptance criteria is to pass two million load cycles with a stress range of 80 MPa without fatigue failure in the anchorage components and with no more than 5% of the tensile element cross-section being lost. Fatigue testing of post-tensioning systems is a new requirement in many parts of the world and passing such a test requires particular care in detailing the components of the anchorage and the transition with the duct.

Load transfer tests for each anchorage type and concrete strength – During a load transfer test, the anchorage components, including relevant reinforcement and concrete with the desired dimensions for a particular concrete strength, are subjected to 10 load cycles between 12% and 80% UTS, before the complete assembly is loaded to failure. An efficiency of at least 110% UTS must be achieved.

Additional mandatory tests are described in EAD16 – such as assembly and grouting tests, as well as a whole range of tests for special applications. Examples include saddle tests for external post-tensioning, tests under cryogenic conditions and electrically isolated tendons.

BBR E-Trace

BBR E-Trace – our in-house developed internet-based software – is a comprehensive e-commerce platform, a quality management tool and engineering database which integrates **Factory Production Control (FPC)**. It links all members of the Global BBR Network including BBR Post-Tensioning Specialists, BBR Component Manufacturers and ETA Holder, BBR VT International.

It leads users through the quality process, ensuring that each step is documented and recorded – including orders, stock management, reception, delivery notes and site management. The platform facilitates the everyday work of all BBR Network members and also supports effective supply chain management.

The BBR E-Trace platform essentially allows us to achieve 100% traceability of every single component that is manufactured along the entire supply chain line, achieve full Factory Production Control and attain CE marking.

Factory Production Control

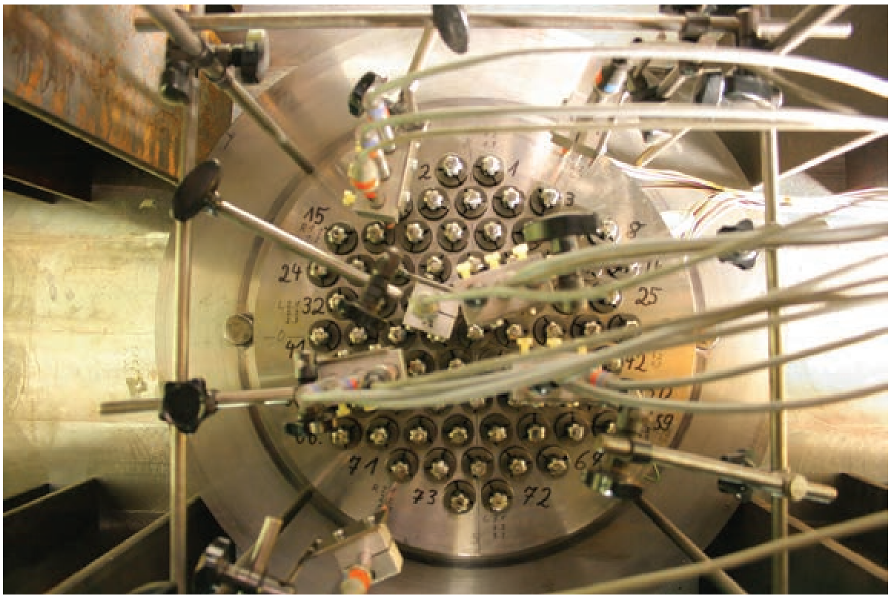
EAD16 specifies the minimum production control frequencies that have to be achieved, e.g. 100% material control, 5% dimension control, 100% visual check.

Compliance with these and the complete factory production process are fully audited by the Approved / Notified Body and any non-conformity must be rectified prior to any CE marking.

During the validity period of the ETA, the Approved / Notified Body continues to exert full control of the production – in addition to the audits and testing by the Kit Manufacturer:

- the ETA Holder and the Kit Manufacturer are audited every year;
- each Component Manufacturer is audited during the five year validity of the ETA;
- kit components are collected from site annually for independent testing and checking of the mechanical performance.

These provisions guarantee proper quality and compliance of the kit components delivered to site.



BBR Post-Tensioning Specialist Companies

European Assessed and CE marked post-tensioning kits must be installed by certified Post-Tensioning Specialist Companies. The BBR Post-Tensioning Specialist Company is responsible, under supervision of the ETA holder, for compliance with all regulations set out in the relevant technical assessments for the post-tensioning kit and with the respective standards and regulations in force at the place of use, and must ensure a professional execution of the post-tensioning works, which includes the following key points:

- logistics and supply of a complete post-tensioning kit to the construction site;
- full assembly and installation service of the post-tensioning kit on the construction site;
- quality assurance and endorsement of all relevant health and safety regulations relating to the work place.

The key personnel of the BBR Post-Tensioning Specialist Company must be continuously trained in the usage of the particular post-tensioning kits and be certified for the post-tensioning works by the ETA Holder – BBR VT International Ltd.

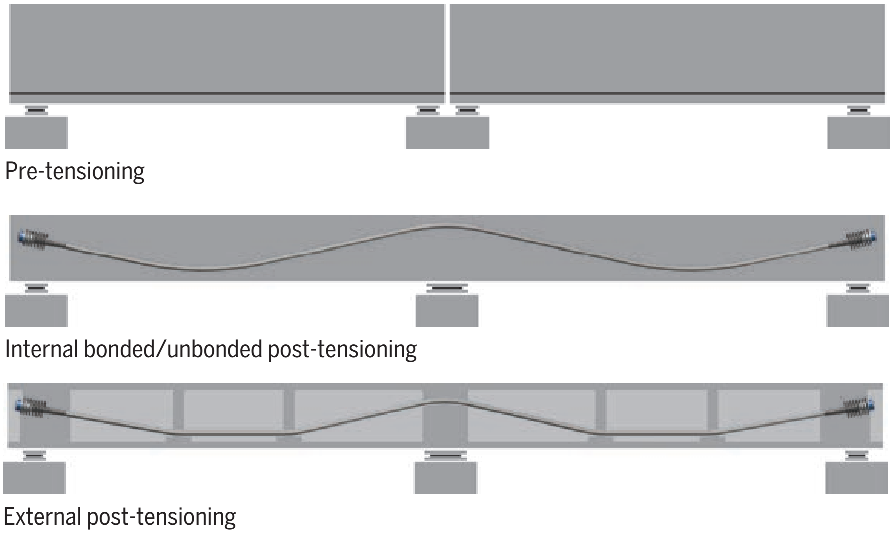
An international passport ensuring the highest standards

The CE marking and the European Technical Assessment create an international passport for post-tensioning kits. CE marked BBR VT CONA CMX post-tensioning systems installed by certified and responsible BBR Post-Tensioning Specialist Companies provide the highest level of quality and assure the owners of the structures to which the post-tensioning kits are applied that only high quality and state-of-the-art products are being used with the required level of safety. The key parameters of all CE marked post-tensioning systems are summarized in the particular ETA which becomes the reference technical document defining the conditions of use of the system. The full ETA document is made available to designers, engineers, contractors and clients.

Efficient and durable construction with post-tensioning

Post-tensioning is a highly effective way of reinforcing concrete while you are building – occasionally even allowing the construction of something which might otherwise have been impossible. It can also be combined with other structural materials, such as steel, masonry and timber. Post-tensioning provides active reinforcement and places the concrete structure under compression in those regions where load causes tensile stress.

Since the first applications in the early 1950s, BBR post-tensioning technology has advanced significantly – particularly in the field of performance, quality assurance and durability, as well as corrosion protection. Massive developments in the post-tensioning method over the past decades mean that it is now a significant feature of construction and is applied to bridges, buildings, arenas, dams, nuclear power stations, wind farms, cryogenic LNG tanks, silos, wastewater treatment plants, water reservoirs, marine structures, retaining walls, towers and tunnels.



Post-tensioning vs. pre-tensioning

Both post-tensioning and pre-tensioning create prestressed concrete. Pre-tensioned systems, however, must be fabricated in a precast plant and are limited to straight, harped or circular tendons. In addition, construction of continuous structures is very limited with this method.

Post-tensioning, on the other hand, allows almost any shape to be constructed and is able to match nearly any design requirement. Internal, bonded, unbonded and external post-tensioning is usually performed on the project site and provides superior corrosion protection features.

Internal vs. external post-tensioning

Tendons installed in the formwork prior to pouring the concrete are known as internal tendons.

External tendons are placed on the outer surface of concrete structures. This type of post-tensioning allows access for maintenance and replacement and is therefore the solution of choice for maintenance, repair and retrofitting (MRR) of bridges, but can also be applied to many other types of structure.

Internal bonded vs. unbonded post-tensioning

Internal bonded post-tensioning systems can range from a single strand to multiple strands (multi-strand) in one tendon. The tendons are inserted into a metal or plastic duct that is embedded in the concrete. By filling the duct with special cementitious grout, the tendon is 'bonded' with the surrounding concrete. The grout creates an alkaline environment which ensures corrosion protection of the prestressing steel.

Unbonded post-tensioning concrete differs from bonded post-tensioning in that it provides each individual tendon with permanent freedom of movement relative to the concrete.

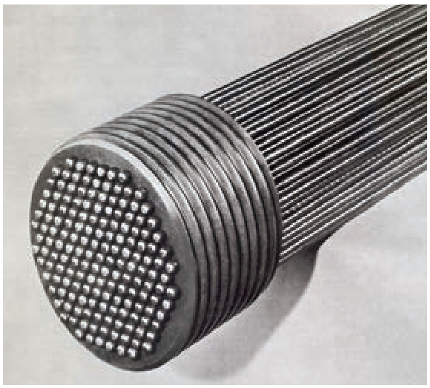
Long history and innovative future

BBR, originally formed as a construction engineering practice over seven decades ago, has proved to be as successful and as durable as the technology it provides. In a track record stretching back over 75 years, BBR post-tensioning has been applied to thousands of different civil engineering structures and buildings.

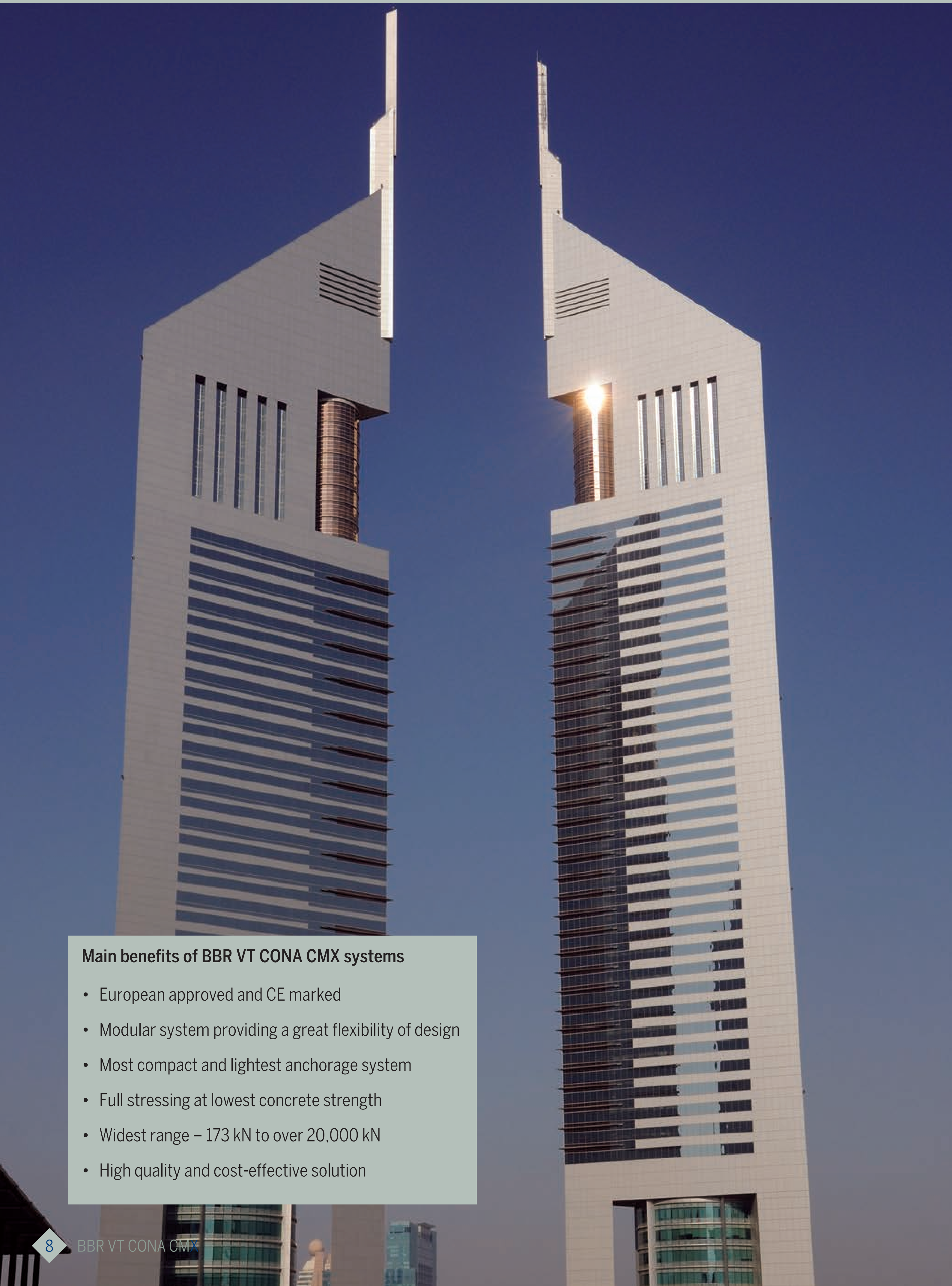
The BBR Network's long history of innovative development began during the Second World War. BBR founders Max Birkenmaier, Antonio Brandestini and Mirko Robin Roš formed a partnership to explore the savings to be made by using pre-tensioned reinforcement for concrete support girders.

Next, they developed the BBRV button headed anchorage configuration which was manufactured from cold-drawn high tensile steel. In the 1950s, the Swiss BBRV post-tensioning kit offered the highest load-bearing capacity available anywhere in the market place. Subsequently, BBR developed a complete range of prestressing and post-tensioning systems covering all structural engineering applications.

Since those early days, there have been many more stories to tell of successes and innovations. The BBR Network's commitment to major technological innovation has been continuous - and is set to continue long into the future.



1944	Company founded by Max Birkenmaier, Antonio Brandestini and Mirko Robin Roš
1945	BBR's first product, the pre-tensioned small beam, was brought to market
1948	Button headed wire post-tensioning system BBRV patented
1955	Construction of first major bridge project – the Andelfingen Viaduct
1965	Prestressing of nuclear power vessels around the world started
1972	Development of BBR CONA Post-Tensioning system
1985	World's largest bridge project – Saudi Arabia-Bahrain Causeway
1996	World's first bridge to use carbon stay cable technology – Storchenbrücke, Switzerland
2005	Launch of latest European approved and CE-marked BBR VT CONA CMX Post-Tensioning series
2009	Launch of BBR E-Trace, the innovative trading and quality assurance platform for CONA CMX systems
2016	Launch of new generation of Advanced BBR VT CMX: Electrically Isolated Tendons, Cryogenic, CMF S2 and CMM S2
2018	Launch of optimized global supply chain



Main benefits of BBR VT CONA CMX systems

- European approved and CE marked
- Modular system providing a great flexibility of design
- Most compact and lightest anchorage system
- Full stressing at lowest concrete strength
- Widest range – 173 kN to over 20,000 kN
- High quality and cost-effective solution

BBR VT CONA CMX Post-tensioning systems

CE marked state-of-the-art post-tensioning kits

The BBR Network offers a complete range of post-tensioning systems, covering all possible applications in structural and civil engineering. The European assessed and highly versatile BBR VT CONA CMX post-tensioning range is used worldwide by the BBR Network.

Its modular design means that a CONA CMX post-tensioning kit can easily be configured to match very special requirements and therefore only the most commonly used configurations are described in this brochure. Please contact the Swiss-based BBR Headquarters or your local BBR Network representative to discuss your specific needs.

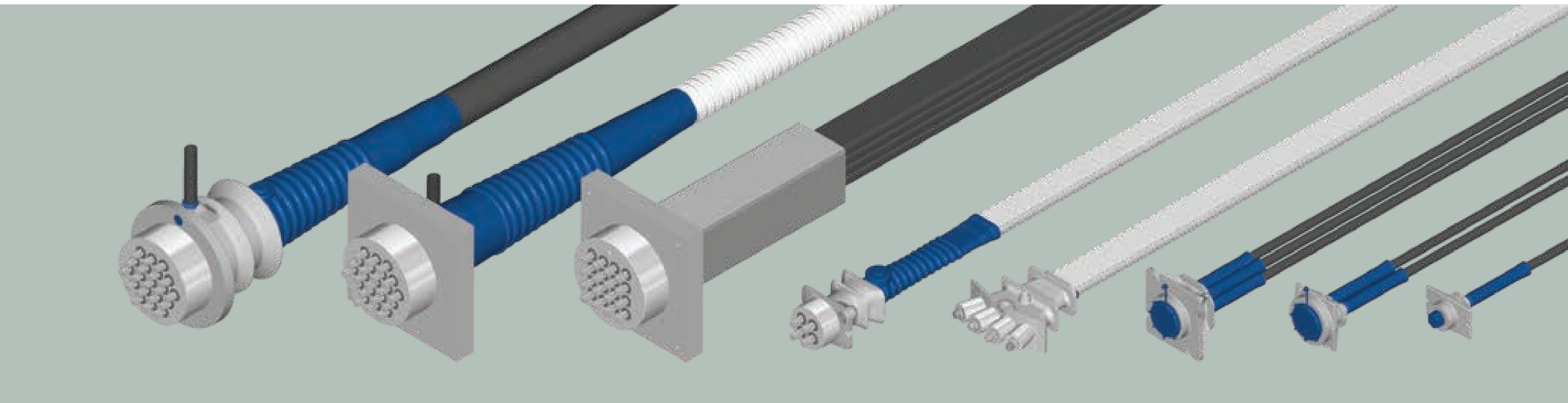
The BBR VT CONA CMX post-tensioning range is comprised of five main systems and several complementary anchorages:

- **BBR VT CONA CMI**
  Internal post-tensioning system
- **BBR VT CONA CME**
  External post-tensioning system
- **BBR VT CONA CMF**
  Flat anchorage post-tensioning system
- **BBR VT CONA CMM**
  Monostrand post-tensioning system
- **BBR VT CONA CMB**
  Band post-tensioning system
- **BBR VT CONA CMO**
  Onion post-tensioning anchorage

BBR VT CONA CMX			CMI	CME	CMF	CMM	CMB
ETA document			06/0147 09/0286 09/0287	07/0168	12/0076	06/0165	10/0065
Range			01-73 1)	01-73 1)	02-06	01-04	01-16
Strand compatibility (inches)			0.5 / 0.6	0.5 / 0.6	0.5 / 0.6	0.5 / 0.6 / 0.6C 2)	0.6 / 0.6C 2)
Usage							
Beam	Internal	Bonded	●	–	●	●	–
		Unbonded	●	–	●	●	–
	External	Unbonded	–	●	–	–	●
		Grouted Unbonded	–	● 3)	–	–	–
Slab	Internal	Bonded	●	–	●	●	–
		Unbonded	●	–	●	●	–
Electrically Isolated Tendons			●	●	–	–	–
Cryogenic			●	–	–	–	●
Anchorage and Coupler							
Stressing (S)			●	●	●	●	●
Fixed (F)			●	●	●	●	●
Dead (D)			△	–	△	△	–
Coupler (K, H or T)			●	●	●	●	–
Anchorage	Monolithic (-)		–	–	–	●	–
	Bearing trumplate (BT)		●	●	●	–	–
	Square plate (SP)		●	●	–	–	●
Intermediate (I)			–	–	–	●	–
Corrosion Protection							
Duct	Steel	Corrugated	●	●	●	●	–
		Smooth	▲	●	▲	●	–
	Plastic	Corrugated	●	●	●	●	–
		Smooth	▲	●	▲	●	● 4)
	BBR Duct	Corrugated	●	●	●	●	–
Monostrand 3)			△	●	●	●	●
Filler	BBR Grout		●	●	●	●	–
	Grease		●	●	●	●	–
	Wax		●	●	●	●	–
Protection Level (*fib*)		PL1	●	●	●	●	●
		PL2	●	●	●	●	●
		PL3	●	●	–	–	–
Page			10	14	18	20	23

● Standard ▲ Standard in unbonded applications. Subject to the regulations in force at the place of use in bonded applications
△ Subject to the regulations in force at the place of use

1) Up to 91 strands on request. 2) compacted strand 15.2mm², 1,820 MPa. 3) Monostrand with factory provided HDPE sheathing and wax/grease
4) Special band sheathing



BBR VT CONA CMI

Internal bonded or unbonded post-tensioning system

Anchorage configuration

The CONA CMI BT (bearing trumplate) system makes use of an advanced and proprietary three plane load transfer, allowing for very small tendon center spacing and concrete edge distances, as well as application of the full post-tensioning load at very low concrete strengths. The anchor has a self-centering feature on the anchor head to ease the installation. The grouting port can be placed at the front or at the upper part of the casting. CONA CMI is compatible with both steel and plastic ducts.

For load transfer to the concrete, the CONA CMI BT can be used for tendon sizes with 02 to 61 strands.

The CONA CMI SP (square plate) is a more traditional system with a single plane load transfer to the concrete providing enough versatility for a variety of works.

For load transfer to the concrete, the CONA CMI SP can be used for 01 to 73 strands.

Anchorage
CONA CMI BT
with BBR VT Plastic Duct

Electrically isolated and cryogenic ready

Anchorage
CONA CMI SP
with corrugated steel duct

KEY FIGURES

Strand compatibility
0.5” and 0.6”

Tendon sizes (strands)
01 - 73 *

Load range
173 - 20,367 kN

Concrete strength at stressing
19/23 MPa

* for larger sizes ask your nearest BBR representative

Fixed and stressable coupler

BBR VT CONA CMI tendons can be coupled using proprietary couplers which can serve as either a stressing or a fixed anchorage coupler. BBR couplers feature a specially designed retaining plate which secures the wedges in non-accessible zones.

Movable Coupler

The movable coupler serves to lengthen unstressed tendons and the tendon elongation during stressing is ensured by a cylindrical sheathing appropriate for the expected elongation at the location of the coupler. Movable couplers may be used to couple continuity tendons at a construction joint. Both coupler types offer a movable version.

Additional features:

- ✓ Stressing anchorage
- ✓ Accessible fixed anchorage
- ✓ Inaccessible fixed anchorage
- ✓ Exchangeable tendons
- ✓ Restressable tendons
- ✓ Electrically isolated tendons (EIT)
- ✓ Cryogenic tendons
- ✓ Loop tendons

CONA CMI Coupler K

Coupler Type K is a single plane coupler which is the perfect solution for projects where space is not a problem. Type K overlap coupler is available for tendons ranging from 2 to 31 strands (larger sizes on request).

Coupler K
CONA CMI BT

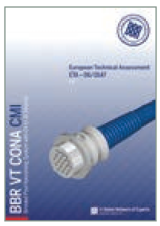
Movable Coupler BK
CONA CMI

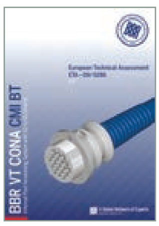
Movable Coupler BH
CONA CMI

CONA CMI Coupler H

Coupler Type H is a two-plane coupler which gives a much more compact solution when the depth of the structure represents a limitation. Type H coupler is available for tendons ranging from 1 to 73 strands.

Coupler H
CONA CMI BT





Available tendon sizes

Type of stands

in	05		06	
mm²	93	100	140	150
MPa	1,860	1,860	1,860	1,860

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]			
01	173	186	260	279
02	346	372	521	558
03	519	558	781	837
04	692	744	1,042	1,116
05	–	–	1,302	1,395
06	–	–	1,562	1,674
07	1,211	1,302	1,823	1,953
08	–	–	2,083	2,232
09	–	–	2,344	2,511
12	2,076	2,232	3,125	3,348
13	–	–	3,385	3,627
15	–	–	3,906	4,185
16	–	–	4,166	4,464
19	3,287	3,534	4,948	5,301
22	–	–	5,729	6,138
24	–	–	6,250	6,696
25	–	–	6,510	6,975
27	–	–	7,031	7,533
31	5,362	5,766	8,072	8,649
37	–	–	9,635	10,323
42	–	–	10,937	11,718
43	–	–	11,197	11,997
48	–	–	12,499	13,392
55	–	–	14,322	15,345
61	–	–	15,884	17,019
69	–	–	17,968	19,251
73	–	–	19,009	20,367

Optional uses for CMI

BBR VT CONA CMI EIT Electrically Isolated Tendons

The European approved CONA CMI Electrically Isolated Tendon (EIT) is the most advanced multi- strand post-tensioning system for eliminating the ingress of chlorides and preventing stray currents from causing electro-chemical corrosion of the steel. These tendons are the best solution for a variety of structures, but are specially recommended for railway structures as well as maritime projects.

CONA CMI EIT tendons are the ideal match for applications including situations where enhanced safety, corrosion protection, quality control, durability and long-term monitoring of post-tensioning tendons are required.

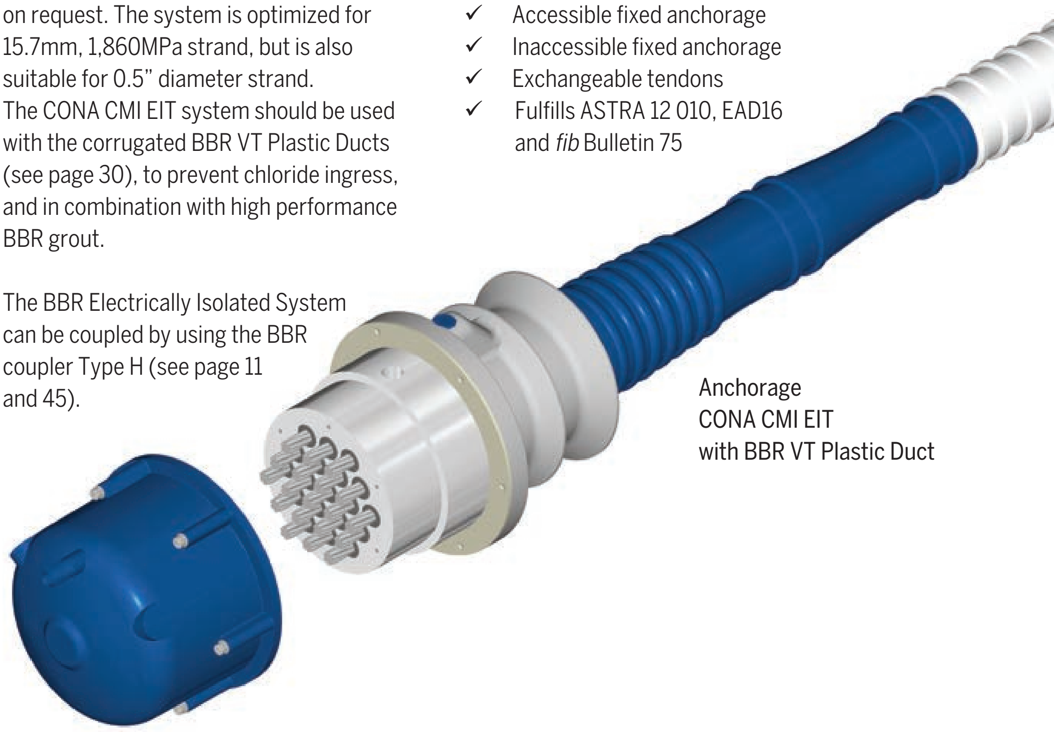
When combined with a simple and non-destructive method of continuously measuring the impedance of the tendons, this is the ultimate post-tensioning system for achieving the highest level of protection - PL3 according to *fib* recommendations (The International Federation for Structural Concrete).

Standard tendon sizes are from 01 to 31 strands, while larger sizes are available on request. The system is optimized for 15.7mm, 1,860MPa strand, but is also suitable for 0.5" diameter strand.
The CONA CMI EIT system should be used with the corrugated BBR VT Plastic Ducts (see page 30), to prevent chloride ingress, and in combination with high performance BBR grout.

The BBR Electrically Isolated System can be coupled by using the BBR coupler Type H (see page 11 and 45).

Main features:

- ✓ Stressing anchorage
- ✓ Accessible fixed anchorage
- ✓ Inaccessible fixed anchorage
- ✓ Exchangeable tendons
- ✓ Fulfills ASTRA 12 010, EAD16 and *fib* Bulletin 75



Anchorage
CONA CMI EIT
with BBR VT Plastic Duct

BBR VT CONA CMI Cryogenic

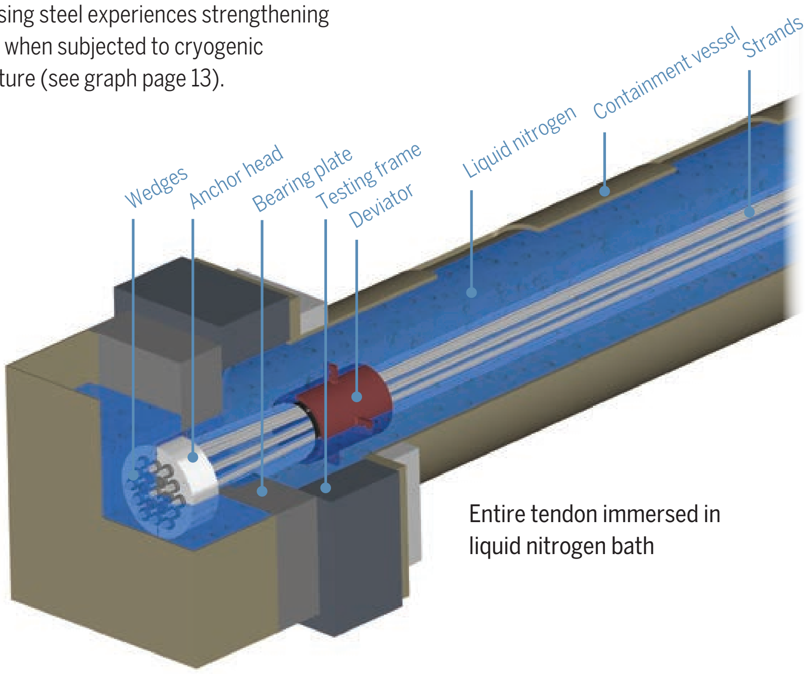
BBR is known as a leading brand in the field of post-tensioning for LNG and LPG tanks. The BBR VT CONA CMI system, designed with cryogenic systems in mind, typically features in the inner and outer walls of the tanks, where tendons are arranged either vertically or horizontally.

The European Organisation for Technical Assessments sets the benchmark for post-tensioning products operating in cryogenic conditions and, as expected, the BBR VT CONA CMI system has met and exceeded every requirement.

The cryogenic test setup with only one anchorage cooled down to the cryogenic temperature is commonly used to verify the performance of post-tensioning systems for cryogenic applications. However, this setup cannot examine the ductility of post-tensioning systems under cryogenic conditions.

When only one anchorage is immersed into a liquid nitrogen bath, the tensile elements (strands) at both ends of the test specimen will be at two different thermal conditions. Part of the tendon near the immersed anchorage is subjected to the cryogenic temperature (-196°C) and the rest of the tendon, which is quite far from the cooling zone, is almost at ambient temperature (+20°C). As known, prestressing steel experiences strengthening behavior when subjected to cryogenic temperature (see graph page 13).

Thereby, the ultimate failure always occurs on the side of the tendon at ambient temperature (see point A on graph), while at this load level the tendon part, which is immersed into the liquid nitrogen bath, is still in the linear elastic zone (see point B).



Entire tendon immersed in liquid nitrogen bath

This means that the ultimate failure force ($f_{max,ambient}$) obtained never reaches the yield point of the strand subjected to the cryogenic temperature ($f_{p0.1,cryogenic}$). The outcome of this test setup does not verify the ductile performance of a post-tensioning system under cryogenic conditions.

Therefore, the BBR R&D department has carried out further tests which have successfully verified the ductility performance of the BBR VT CONA CMI post-tensioning system with normal grade anti-bursting reinforcement. These tests prove that the CONA CMI system is in full compliance with the EAD16 testing regime under both temporary and permanent cryogenic conditions without any need to use costly low temperature grade reinforcement and thus delivering significant material cost savings.

*See also BBR Network LNG Tanks Reference List brochure.

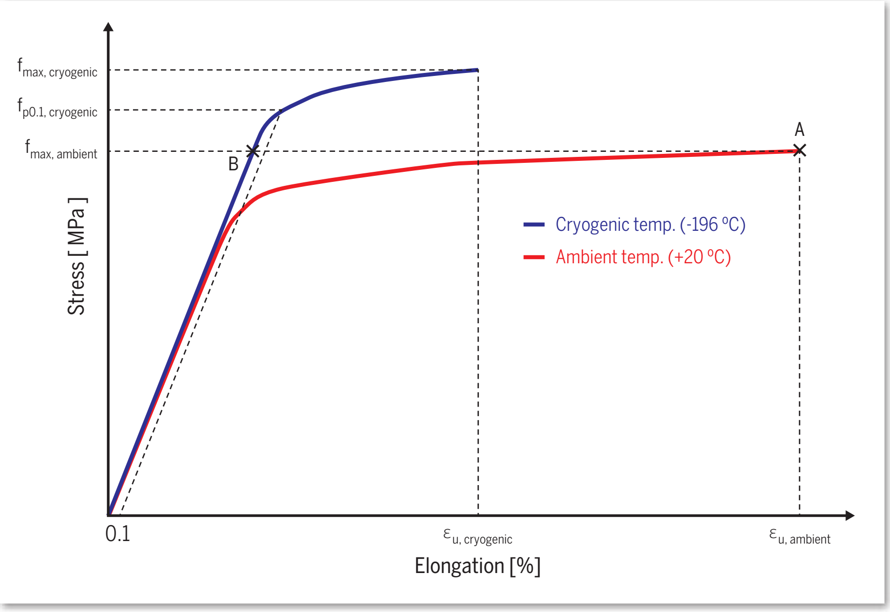


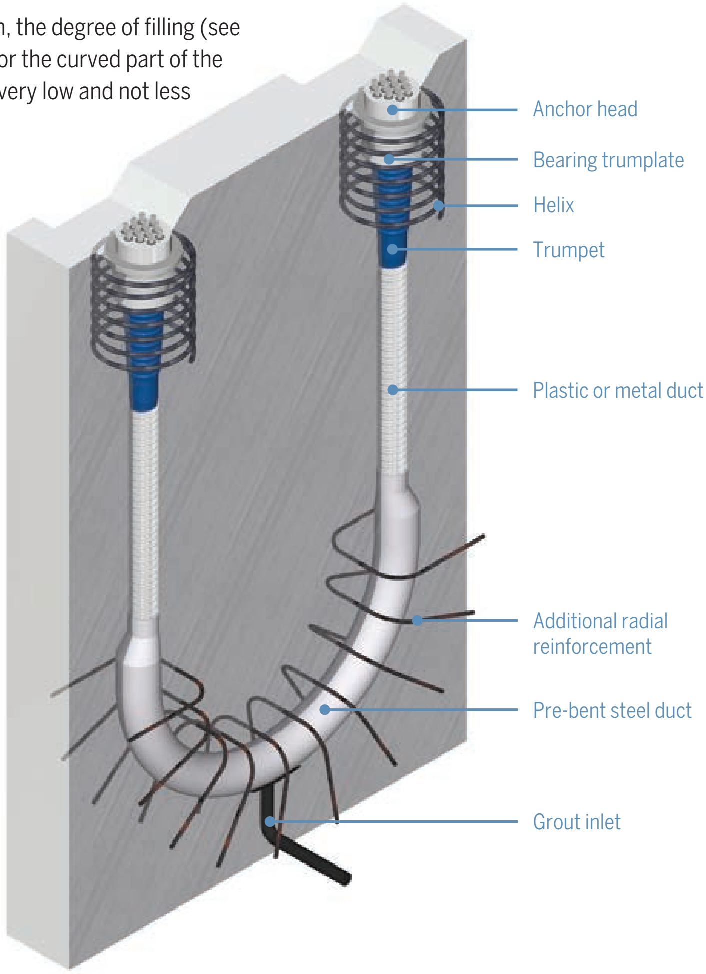
Figure 1: Static tensile test results comparing post-tensioning strands at different temperatures

BBR Loop Tendon

Loop tendons are often used when there is no access to the dead end – for example for vertical post-tensioning in tanks and silos. In this scenario, the straight part of the tendon is inside the concrete wall and the loop is in the base of the tank. Whilst termination of post-tensioning strands at the base of a tank is not impossible, the reinforcing steel is usually already congested in this area and therefore adding a post-tensioning strand termination here can be problematic.

Use of the BBR Loop Tendon system reduces congestion at the base of the tank and allows anchorage and stressing detailing to be minimized to the top of the tank. Minimum radii of curvatures of up to 0.7m are achievable, which is considerably less than the minimum bending radius of a normal prestressing strand.

Due to the reduced radius of curvature, the contact pressure between the strands and the duct becomes very high, $p_{R,max}$ > 800 kN/m. For the straight part of the tendon, corrugated steel or plastic ducts can be used, whereas a smooth steel duct is selected for the curved portion in order to dissipate the high contact pressures. For ease of installation, the degree of filling (see page 37) chosen for the curved part of the tendon should be very low and not less than 0.25.



BBR VT CONA CME

External post-tensioning system

Anchorage configuration

Both CONA CME systems use the same bearing trumplate - a multi-plane anchorage and the square plate, a single plane anchorage - as the BBR VT CONA CMI system. However, the BBR VT CONA CME system requires a deviator/saddle element and the usage of smooth ducts of steel or plastic.

For load transfer to the concrete, the CONA CME BT (bearing trumplate) can be used for tendon sizes from 2 to 61 strands and the CONA CME SP (square plate) can be used for 1 to 73 strands.

Deviator / Saddle

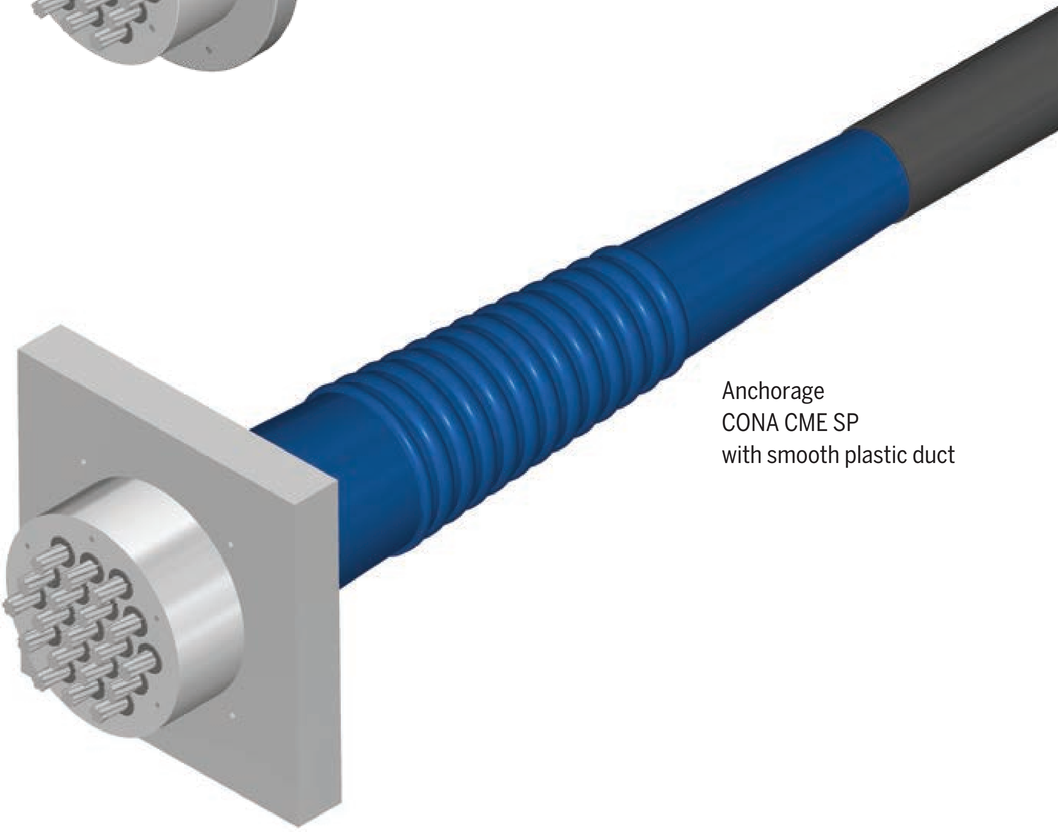
An element that is specific to external prestressing is the deviator/saddle. The deviator transfers the transversal forces generated by the tendon to the structure and provides a smooth surface for the tendons. The deviator can be made of concrete, steel, HDPE or equivalent.

Lowest radius of curvature on the market place

Additional features:

- ✓ Stressing anchorage
- ✓ Accessible fixed anchorage
- ✓ Inaccessible fixed anchorage
- ✓ Exchangeable tendons
- ✓ Restressable tendons
- ✓ Electrically isolated tendons (EIT)
- ✓ Coupler H and K compatibility

Anchorage
CONA CME BT
with smooth plastic duct



Anchorage
CONA CME SP
with smooth plastic duct

KEY FIGURES

Strand compatibility
0.5" and 0.6"

Tendon sizes (strands)
01 - 73 *

Load range
260 - 20,367 kN

Concrete strength at stressing
19/23 MPa

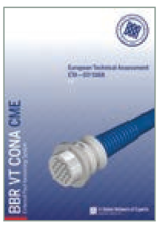
* for larger sizes ask your nearest BBR representative

Coupler

Although less common for external tendons, CONA CME tendons can be coupled using proprietary Type K overlap coupler for tendons ranging from 2 to 31 strands (larger sizes on request) or Type H sleeve coupler for 1 to 73 strands.

Coupler K
CONA CME

Coupler H
CONA CME



Available tendon sizes

Type of stands

in	06	
mm^2	140	150
MPa	1,860	1,860

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]	
01	260	279
02	521	558
03	781	837
04	1,042	1,116
05	1,302	1,395
06	1,562	1,674
07	1,823	1,953
08	2,083	2,232
09	2,344	2,511
12	3,125	3,348
13	3,385	3,627
15	3,906	4,185
16	4,166	4,464
19	4,948	5,301
22	5,729	6,138
24	6,250	6,696
25	6,510	6,975
27	7,031	7,533
31	8,072	8,649
37	9,635	10,323
42	10,937	11,718
43	11,197	11,997
48	12,499	13,392
55	14,322	15,345
61	15,884	17,019
69	17,968	19,251
73	19,009	20,367

Optional uses for CME

BBR is always leading the way with innovative solutions that meet construction industry needs. Now we blend improved corrosion protection and exchangeability to offer BBR VT CONA CME monostrand and BBR VT CONA CME exchangeable post-tensioning systems. These systems not only permit tendons to be exchanged, but they are also suitable for use as electrically isolated tendons (EIT).

BBR VT CONA CME Monostrand

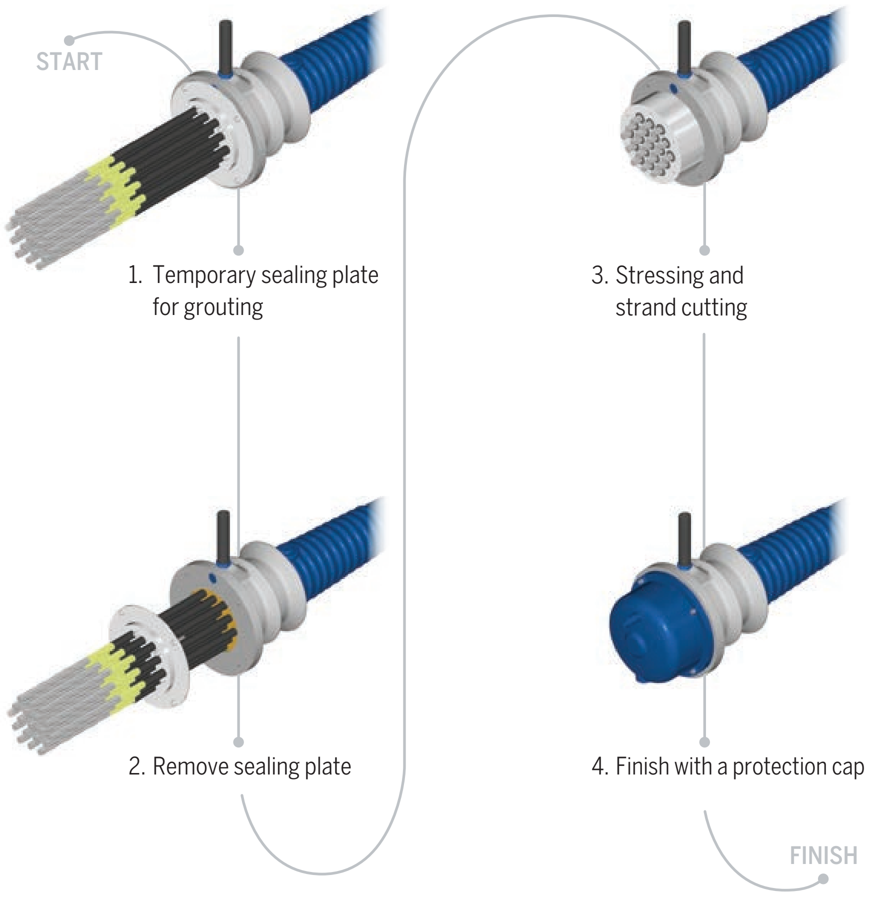
Smallest radius of curvature and multi-layer corrosion protection
For the new BBR VT CONA CME BT with monostrand solution, monostrands are placed in a duct that is grouted prior to stressing. During grouting, a temporary sealing plate together with an activation plate is installed at the anchorage to arrange the monostrands and resist the grouting pressure. After grouting, the monostrand ends are de-sheathed. For stressing, the anchor head is placed on the grouted tendon. Stressing can begin once the compressive strength of the grout is sufficiently developed. This solution is applicable to BT anchorages, as well as K and H coupling anchorages.

The key advantages and features of this solution are:

- Smallest radius of curvature – 2.5m.
- Multiple layers of corrosion protection – duct, grout and finally monostrand (which incorporates PE sheathing/grease).
- Cost-efficient as cement grout is used, instead of grease or wax.
- Restressable and exchangeable strands.

Exchange of tendons with monostrands is generally performed via the strand-by-strand method, individually for each monostrand. After exchanging the prestressing steel strands, the monostrands are then refilled with corrosion protection material. BBR VT CONA CME tendons are compatible with fixed coupler Type H and K.

BBR VT CONA CME Monostrand assembly sequence



Advantages / Key features	CME with bare strand	CME - Monostrand
Applications	Unbonded	Unbonded
Type of filler	Grease / Wax	Grout
Level of corrosion protection	2 (duct and filler)	4 (duct, grout, HDPE sheathed monostrand)
Minimum radius of curvature	2.0m to 4.0m (based on size of tendon)	maximum 2.5m
Re-stressability	✓	✓
Exchangeability	✓	✓

BBR VT CONA CME Exchangeable Tendon

BBR VT CONA CME BT Exchangeable Tendons with/without electrical isolation is an option available for:

- Bare strands with grease, wax, or an equivalent corrosion inhibitor.
- Monostrands grouted in a duct.
- Bare strands, grouted in a duct.

Even where bare strand grouted in the duct has been used, a BBR VT CONA CME BT tendon can be completely removed and subsequently replaced by a new tendon.

The main components in the anchor zone of the CONA CME BT Exchangeable Tendon with bare strand grouted in the duct are the protection cap, wedges, anchor head, load transfer element (bearing trumplate), outer trumpet and inner trumpet.

The inner trumpet is placed in the bearing trumplate and the trumpet extends up to the anchor head (or steel ring for EIT) and provides a separating layer between structure and tendon. In the case of a tendon with electrical isolation, the protection cap - with the help of the isolation ring - encapsulates the whole anchor head with the wedges and locked strand. This innovative solution can also be coupled with fixed coupler Type H.

Anchorage
CONA CME EIT
with smooth HDPE duct

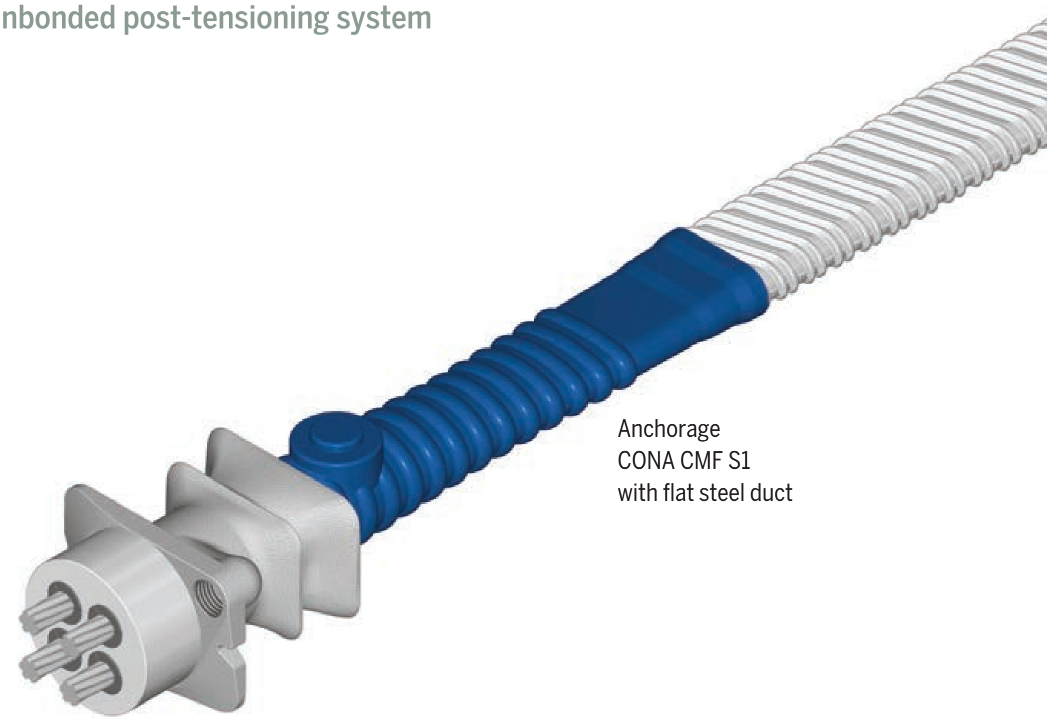
Anchorage
CONA CME Exchangeable
with smooth HDPE duct

BBR VT CONA CMF S1

Flat anchorage internal bonded or unbonded post-tensioning system

Anchorage configuration

The CONA CMF S1 is a bonded or unbonded post-tensioning solution for projects ranging from 2 to 4 strands. For load transfer to the concrete, the CONA CMF BT (bearing trumplate) is used, which makes use of an advanced and proprietary three plane load transfer especially developed for anchoring in thin cross-sections. This allows for very small center and edge distances at the anchorages, as well as application of the full post-tensioning load at very low concrete strengths. The system is also compatible with CONA CMI anchor heads, offering easier operations and simplifying stock management. Furthermore, it can be used with both steel and plastic ducts.



Anchorage
CONA CMF S1
with flat steel duct

Coupler

CONA CMF S1 tendons can be coupled using proprietary Type H sleeve couplers. The coupler can serve as a stressing / active anchorage coupler or fixed / passive anchorage coupler bearing against the bearing trumplate or as movable couplers along the length of the tendon.

Coupler H
CONA CMF S1

Movable Coupler BH
CONA CMF S1

KEY FIGURES

Strand compatibility
0.5" and 0.6"

Tendon sizes (strands)
02 - 04

Load range
346 - 1,116 kN

Concrete strength at stressing
17/21 MPa

Available tendon sizes

Type of stand

in	05		06	
mm^2	93	100	140	150
MPa	1,860	1,860	1,860	1,860

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]			
02	346	372	521	558
03	519	558	781	837
04	692	744	1,042	1,116

BBR VT CONA CMF S2

Flat anchorage internal bonded or unbonded post-tensioning system

Anchorage configuration

The CONA CMF S2 system is the most advanced internal bonded or unbonded solution for slab projects and uses the versatile barrel-wedge concept.

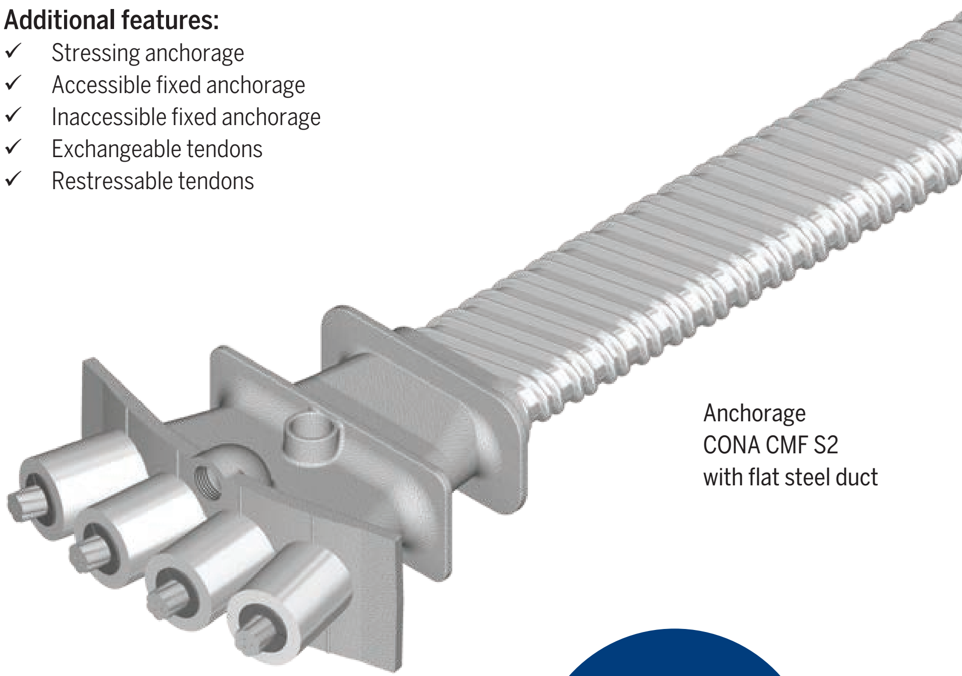
The design of this system allows center spacings and edge distances to be minimized to reduce slab thickness.

It is suitable for both bonded and unbonded applications and has been optimized for strand sizes of 0.5" and 0.6". Also, it is compatible with flat steel and plastic ducts.

The CONA CMF S2 can be used for tendon sizes from 02 to 06 using 0.5" strand, and from 02 to 05 for 0.6" strand.

Additional features:

- ✓ Stressing anchorage
- ✓ Accessible fixed anchorage
- ✓ Inaccessible fixed anchorage
- ✓ Exchangeable tendons
- ✓ Restressable tendons



Anchorage
CONA CMF S2
with flat steel duct

Achieves the thinnest concrete slab on the market

KEY FIGURES

Strand compatibility
0.5" and 0.6"

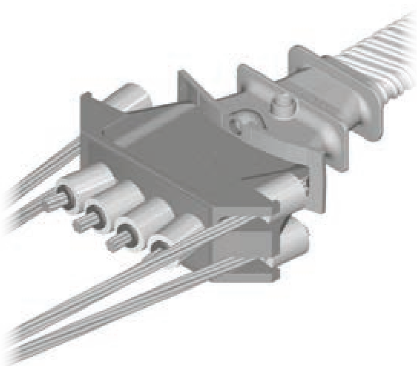
Tendon sizes (strands)
02 - 06

Load range
346 - 1,395 kN

Concrete strength at stressing
21/26 MPa

Coupler

The CONA CMF S2 is compatible with a special fixed coupler Type K to keep slab thickness as low as possible.



Coupler K
CONA CMF S2

Available tendon sizes

Type of stand

in	05		06	
mm²	93	100	140	150
MPa	1,860	1,860	1,860	1,860

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]			
02	346	372	521	558
03	519	558	781	837
04	692	744	1,042	1,116
05	865	930	1,302	1,395
06	1,038	1,116	–	–

BBR VT CONA CMM Single S1

Monostrand bonded or unbonded post-tensioning system

Anchorage configuration

The CONA CMM Single S1 is a versatile system where you can have a bonded solution using a single strand with BBR Grout inside of a steel or plastic duct, or unbonded solution using a greased monostrand with HDPE sheathing.

KEY FIGURES

Strand compatibility
0.6" and 0.6"C

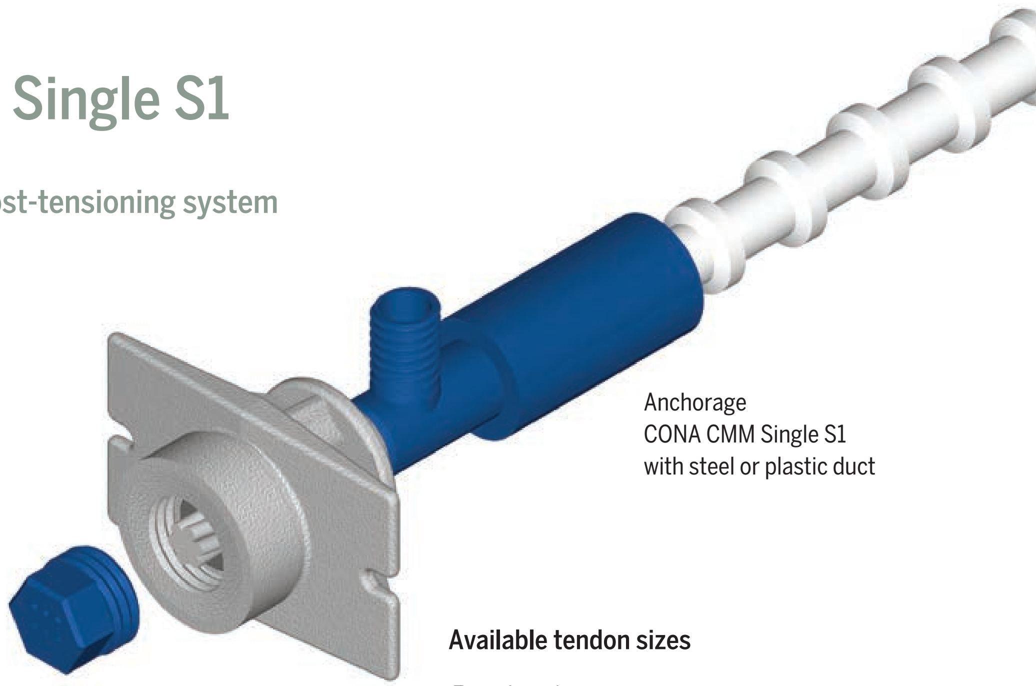
Strand type
Bare/monostrand

Applications
Bonded/unbonded

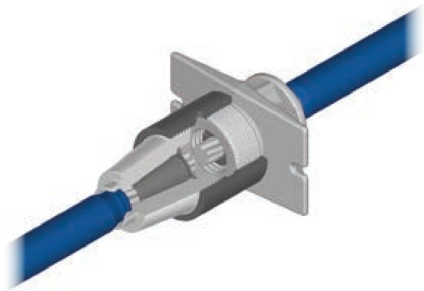
Concrete strength at stressing
20/24 MPa

Coupler

CONA CMM Single S1 tendons can be coupled using a proprietary Type H sleeve coupler which is threaded to the monolithic anchorage.



Anchorage
CONA CMM Single S1
with steel or plastic duct



Coupler H
CONA CMM Single S1

Available tendon sizes

Type of stand

in	06		06C
mm^2	140	150	165
MPa	1,860	1,860	1,820

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]		
01	260	279	300

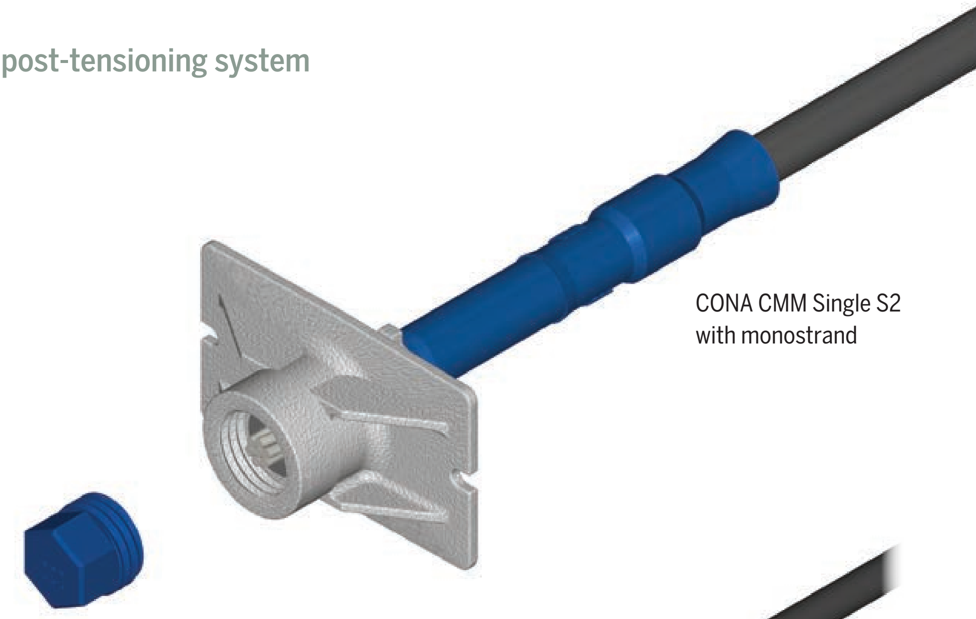
BBR VT CONA CMM Single S2

Monostrand bonded or unbonded post-tensioning system

Anchorage configuration

The CONA CMM Single S2 has been developed to enhance productivity on site. The concrete strength at stressing is lower than ever and a full set of accessories has been designed, such as the clip-lock chair to centralize the anti-bursting steel which saves installation time.

The system has been optimized to minimize center spacings and edge distances, while removing the need for anti-bursting steel in the anchorage zone subject to adherence to minimum center spacing.



CONA CMM Single S2 with monostrand

KEY FIGURES

Strand compatibility
0.5" and 0.6"

Strand type
Bare/monostrand

Applications
Bonded/unbonded

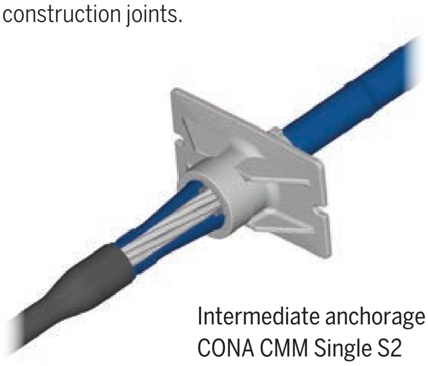
Concrete strength at stressing
18/22 MPa

No anti-bursting steel needed

Greased monostrand with HDPE sheathing and single strand with cement grouted duct

Intermediate anchorage

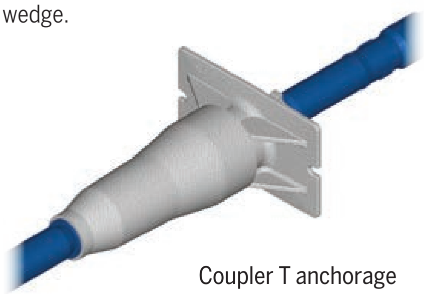
The CONA CMM Single S2 intermediate anchorage allows installation of a full tendon without the need to cut the strand at construction joints.



Intermediate anchorage CONA CMM Single S2

Coupler

CONA CMM Single S2 tendons can be also coupled using an enhanced proprietary Type T monolithic coupler with a pre-installed wedge.



Coupler T anchorage CONA CMM Single S2

Tendon flexibility

CONA CMM is compatible with bonded applications using bare strand and steel or plastic duct filled with grout, and also unbonded applications using greased monostrand with HDPE sheathing.

Available tendon sizes

Type of stand

in	05		06	
mm^2	93	100	140	150
MPa	1,860	1,860	1,860	1,860

Tendon sizes

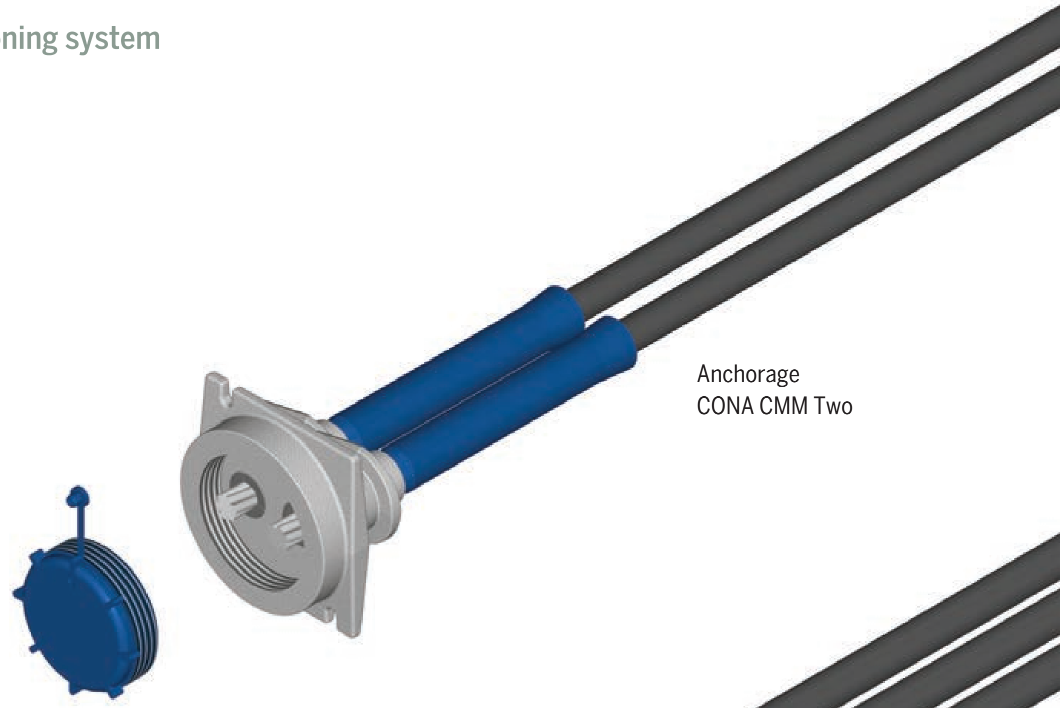
Strands	Characteristic ultimate resistance of tendon [kN]			
01	173	186	260	279

BBR VT CONA CMM Two/Four

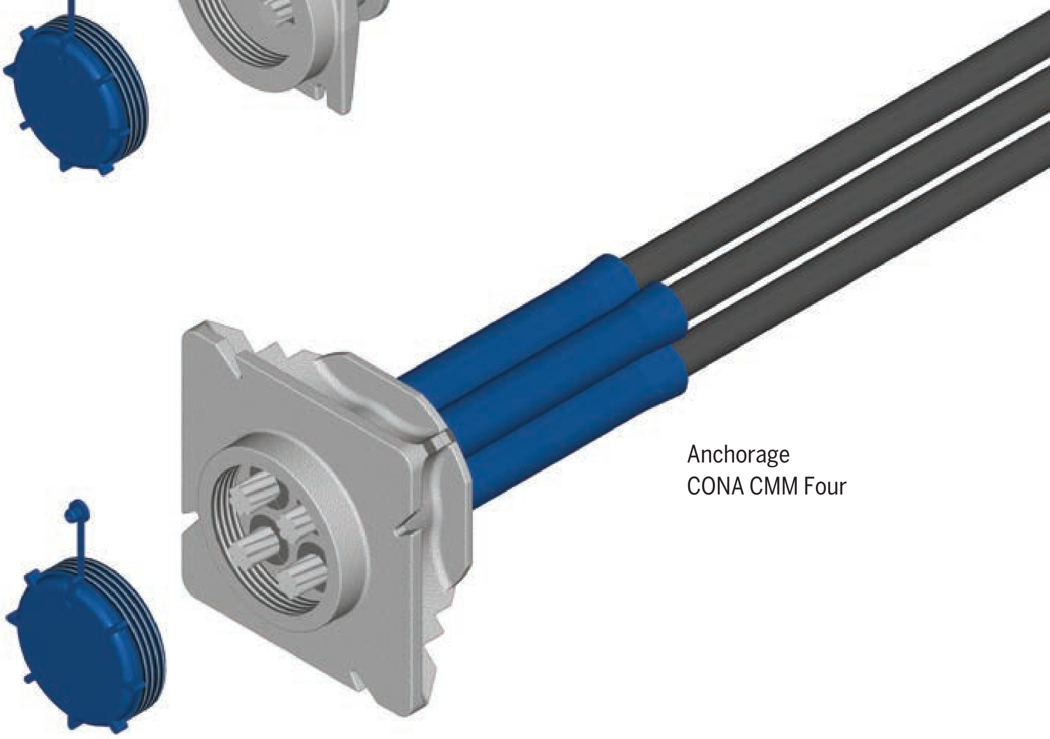
Monostrand unbonded post-tensioning system

Anchorage configuration
The main components in the anchor zone of the CONA CMM system are the wedges, monolithic anchorage and individual transition pipes.

In the anchorage zone, the strands are guided through the transition pipes to the monolithic anchorage, where each strand is individually locked with special BBR wedges. The anchoring of the strand and load transfer to the concrete is carried out with one and the same unit, allowing for a high economy, small center and edge distances at the anchorages, as well as application of the full post-tensioning load at very low concrete strengths.



Anchorage
CONA CMM Two



Anchorage
CONA CMM Four

KEY FIGURES

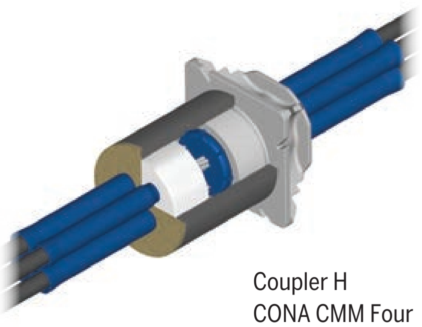
Strand compatibility
0.6" and 0.6"C

Tendon sizes (strands)
02 or 04

Strand type
Monostrand

Concrete strength at stressing
20/24 MPa

Coupler
CONA CMM Four tendons can be coupled using a proprietary Type H sleeve coupler. The couplers can serve as a stressing / active anchorage coupler or fixed / passive anchorage coupler during the first construction stage.



Coupler H
CONA CMM Four

Available tendon sizes

Type of stand

in	06		06C
mm²	140	150	165
MPa	1,860	1,860	1,820

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]		
02	521	558	601
04	1,042	1,116	1,201

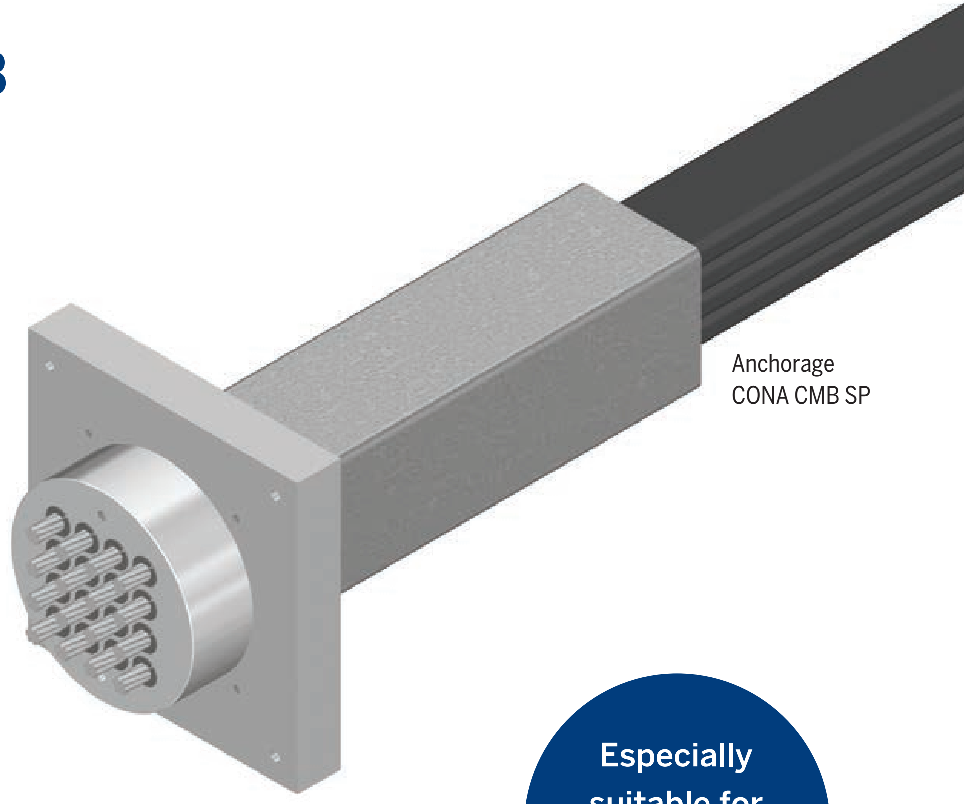
BBR VT CONA CMB

Band post-tensioning system

Anchorage configuration
The main components in the anchor zone of the CONA CMB SP system are the wedges, anchor head, load transfer element and the recess tube. In the anchorage zone, the strand bundle is spread out towards the anchor head, where each strand is individually locked with BBR wedges. For load transfer to the concrete, the CONA CMB SP (square plate) is used.

Deviator / saddle
An element that is specific to external prestressing is the deviator/saddle. The deviator transfers the transversal forces generated by the tendon to the structure and provides a smooth surface for the tendons. The deviator can be made of concrete, steel, HDPE or equivalent.

Corrosion protection
The strands are greased/waxed and individually sheathed in the factory with continuously extruded HDPE sheathing and subsequently grouped parallel. There are two options - single sheathing or double sheathing.

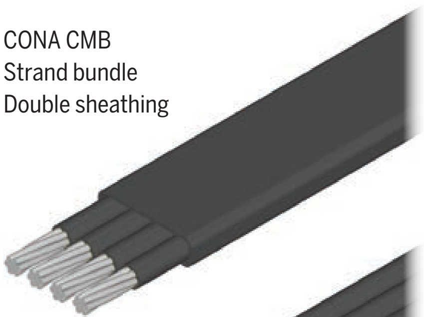


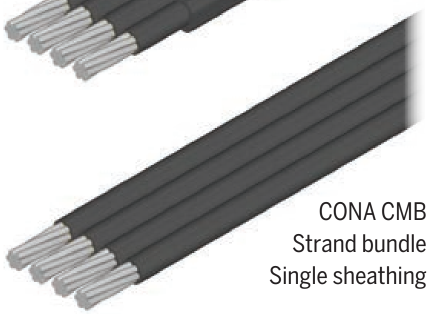
Anchorage
CONA CMB SP

Especially suitable for strengthening and repair

Band configuration

CONA CMB
Strand bundle
Double sheathing





CONA CMB
Strand bundle
Single sheathing

KEY FIGURES

Strand compatibility
0.6" and 0.6"C

Tendon sizes (strands)
01 - 16

Load range
260 - 4,805 kN

Concrete strength at stressing
29/35 MPa

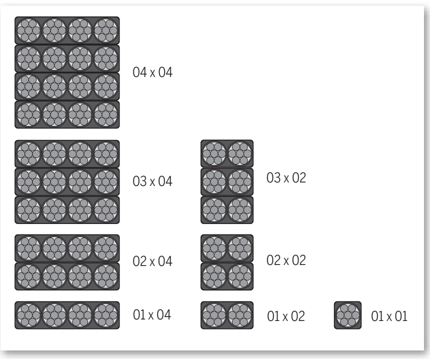
Available tendon sizes

Type of stand

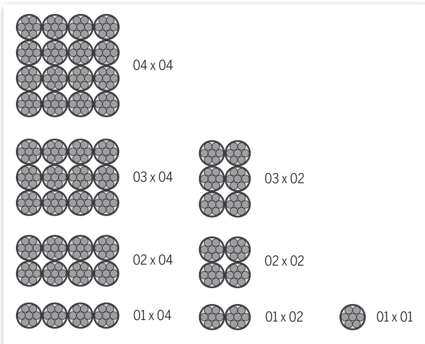
in	06		06C
mm^2	140	150	165
MPa	1,860	1,860	1,820

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]		
01	260	279	300
02	521	558	601
04	1,042	1,116	1,201
06	1,562	1,674	1,802
08	2,083	2,232	2,402
12	3,125	3,348	3,604
16	4,166	4,464	4,805



CONA CMB Strand bundle double sheathing



CONA CMB Strand bundle single sheathing

BBR VT CONA CMO

Complementary bond anchorage

BBR VT CONA CMO, as a complementary anchorage, is compatible with other BBR post-tensioning systems such as BBR VT CONA CMF and BBR VT CONA CMI.

Innovations include a clip-lock strand spacer and duct sealing filler to enhance productivity on site – and the need for local anti-bursting steel has been removed, saving installation time, materials and cost.

No anti-bursting steel needed

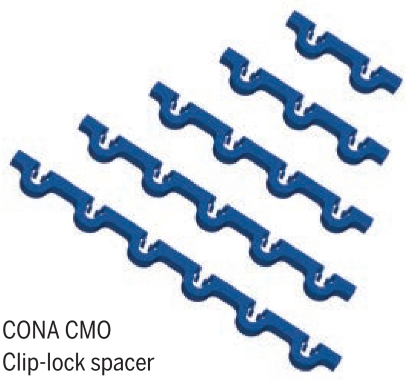
KEY FIGURES

Strand compatibility
0.5" and 0.6"

Tendon sizes (strands)
02 - 06

Load range
346 - 1,674 kN

Concrete strength at stressing
21/26 MPa



CONA CMO
Clip-lock spacer

Available tendon sizes

Type of stand

in	05		06	
mm^2	93	100	140	150
MPa	1,860	1,860	1,860	1,860

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]			
02	346	372	521	558
03	519	558	781	837
04	692	744	1,042	1,116
05	865	930	1,302	1,395
06	1,038	1,116	1,562	1,674

BBR VT CONA CMW

Complementary anchorage

The BBR VT CONA CMW system has been designed for circular structures such as tanks and silos. The CONA CMW anchorage is used to wrap tanks without the need for a buttress, saving valuable time and cost – and has proved particularly effective for retrofit and strengthening projects.

The anchorage is compatible with steel or plastic ducts and can be used with bare strands and monostrands.

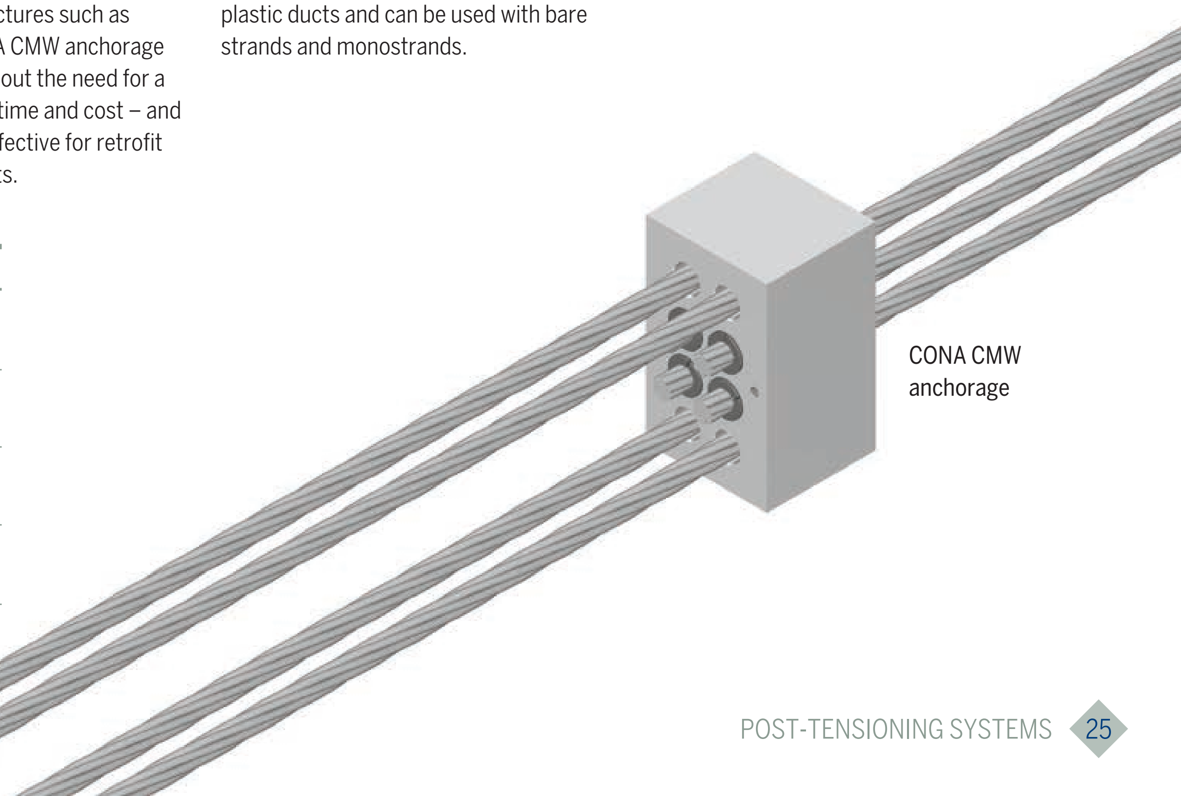
KEY FIGURES

Strand compatibility
0.6" and 0.6"C

Tendon sizes (strands)
02 - 06

Strand type
Bare/monostrand

Duct
Steel/plastic



Professional installation practice

The highest level of professionalism is required for post-tensioning and grouting operations – precisely what our certified BBR Post-Tensioning Specialists, BBR Network Members, deliver. The continuous practical and theoretical education of these well-trained and experienced staff ensures professional execution of post-tensioning services.

Post-tensioning is installed in four main stages:

1. Duct and anchorage installation
The installation of a post-tensioning system starts by fitting the anchorages, laying out the ducts and positioning the anti-bursting steel. The anchorages are fixed to the formwork by bolts. Duct is installed and connected to the anchorage. For internal prestressing, the ducts – most commonly made of corrugated steel or HDPE sheathing – are positioned before concreting. In the case of external prestressing, HDPE tubes are the most commonly used ducts. Positioning and support of the ducts is completed with special care and attention.

2. Strand threading
Free passage in the ducts is checked before the strands are threaded. Generally, this takes place by pushing each strand from one end of the duct.

3. Stressing
Tendons are stressed using single strand or multistrand hydraulic jacks with hydraulic locking-off of the anchor jaws.
Space requirements for stressing jacks and anchorage recess details in the immediate vicinity of a post-tensioning anchor are shown in Table 1. These requirements and details are only for guidance and should always be verified with a local BBR Network Member.

4.Grouting / finishing
Grout is key to ensuring the performance and durability of the tendons and therefore also for the whole structure. Before grouting, the anchor head must be sealed by using BBR caps in order to ensure the maximum quality. Grouting is unnecessary for unbonded tendons, therefore the finishing consists of sealing the tendon, using BBR accessories - by injecting grease in those anchorages that allow it to protect the strand end and wedge.

Table 1: Space requirements for stressing jacks and anchor recesses

Tendon Unit		CMF S1 3)	CMF S2	CMM Single S1	CMM Single S2	CMM Two	CMM Four	04 06	07 06	12 06	19 06	22 06	31 06	42 06	55 06	61 06
Dimensions (mm) 1), 4)	A x A	100 x 100 2)	90 x 230 2)	70	60	125	125	230	270	340	420	420	460	560	650	715
	B	110	110	45	45	45	45	140	140	150	165	165	185	200	225	250
	C x C	140 x 200 2)	110 x 270 2)	110	100	200	200	310	370	400	510	510	560	660	750	815
	D	1,100	800	800	800	1,250	1,300	1,400	1,500	1,600	1,720	1,810	2,000	2,300	2,600	2,900
	E	170	170	90	90	110	150	250	300	330	345	400	480	600	600	600
	F	170	80	70	55	90	110	200	230	260	280	330	380	420	450	480

1) Jack spacing requirements and recess detailing are for guidance purposes only and should be verified with your local BBR Network Member. 2) Recess details are rectangular as indicated. 3) The recess details indicated are for use with a grout port extending from the trumpet. If the grout port is extended from the bearing trumplate, a larger recess detail is required. 4) In case of narrow space or larger jack sizes, please contact your local BBR Network Member.

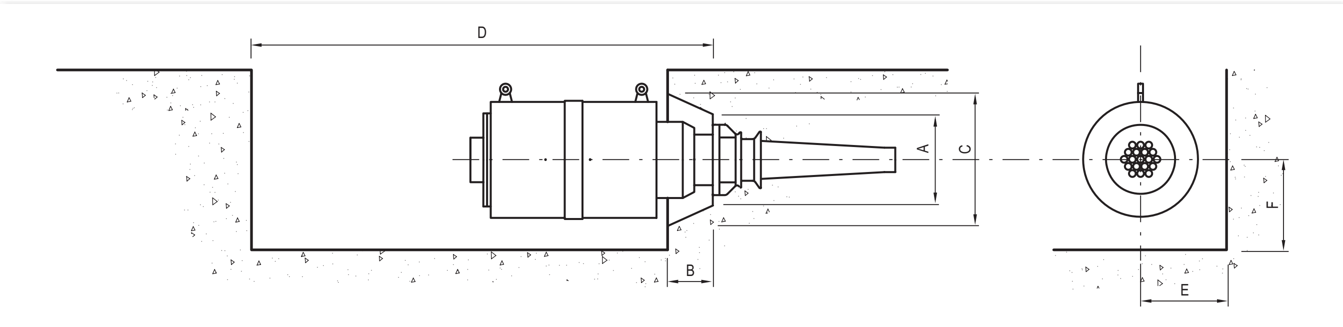


Figure 2: Dimensions of space requirements

Materials

Strand

Seven-wire strands comprise a central wire, normally identified as ‘king wire’, and an external crown of six wires which are twisted around the king wire. Strands with a characteristic tensile strength equal to 1,860 MPa are normally used – however steel strands with a lower characteristic strength, 1,770 MPa or 1,820 MPa, may also be used. The characteristic values of the standard strands are shown in Table 2.

Other suitable strands according to standards and regulations valid at the place of use may also be used, such as for example the ones shown in prEN 10138-3, ASTM A416 and AS/NZS 4672 standards.

Table 2: Typical strand material properties to prEN 10138-3

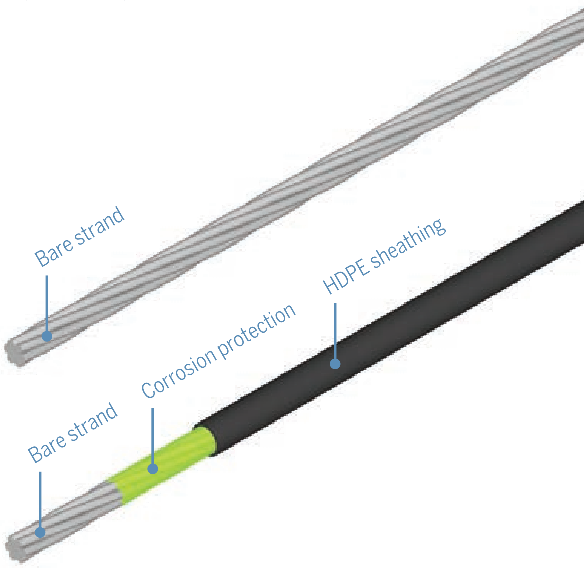
Type of strands			05		06				06C
Characteristic tensile strength	f_{pk}	MPa	1,770	1,860	1,770	1,860	1,770	1,860	1,820
Characteristic value of maximum force	F_{pk}	kN	177	186	248	260	266	279	300
Characteristic value of 0.1% proof force	$F_{p0.1}$	kN	156	164	218	229	234	246	264
Nominal diameter	d	mm	12.9		15.3		15.7		15.2
Nominal cross-sectional area	A_p	mm²	100		140		150		165
Mass of prestressing steel	M	kg/m	0.781		1.093		1.172		1.289
Minimum elongation at maximum force	A_{gt}	%	3.5						
Modulus of elasticity	E_p	MPa	approx. 195,000						
Greased/waxed monostrands are sheathed in the factory with continuously extruded HDPE sheathing									
External diameter of strand (incl. HDPE)	≈	mm	17		19.5		20		20
Mass of strand (incl. grease/wax and HDPE)	≈	kg/m	0.90		1.23		1.31		1.40

There are two basic strand configurations:

- bare strands for bonded and unbonded applications;
- monostrands with a factory-provided corrosion protection system consisting of corrosion protection grease/wax and HDPE sheathing for unbonded applications.

Monostrands have to fulfill:

- minimum 1.0 mm thickness of sheathing;
- at least 18 MPa tensile strength and at least 450% elongation at 23 °C;
- no visual damage, no bubbles and no visible traces of filling material on the surface of the sheathing;
- no cracking after 72 hours in a tensioactive liquid at 50 °C;
- variation of tensile strength and elongation at 23 °C after conditioning for 3 days at 100 °C less than 25%;
- less than 60 N/m friction between sheathing and strand;
- no water leaking through specimen.



Concrete

Compressive strength of concrete in accordance with EN 206 is defined by the characteristic value f_{ck} (5% fractile of normal distribution) obtained in compressive tests executed at 28 days after casting of cylindrical specimens of diameter 150 mm diameter and 300 mm height or 150 mm cubic specimens. Compressive strength classes are denoted by the letter C followed by two numbers that indicate the cylinder and cube characteristic strength, expressed in MPa, for example C20/25.

Figure 3 shows an ideal distribution of the values of compressive strength for concrete specimens. In the figure, the curve peak coincides with the average of the compressive strength and is normally known as the mean compressive strength, f_{cm}. The characteristic compressive strength is lower than the mean compressive strength and both may typically be related with the following expression:

$f_{ck,cylinder} \approx f_{cm,cylinder} - 8$ MPa

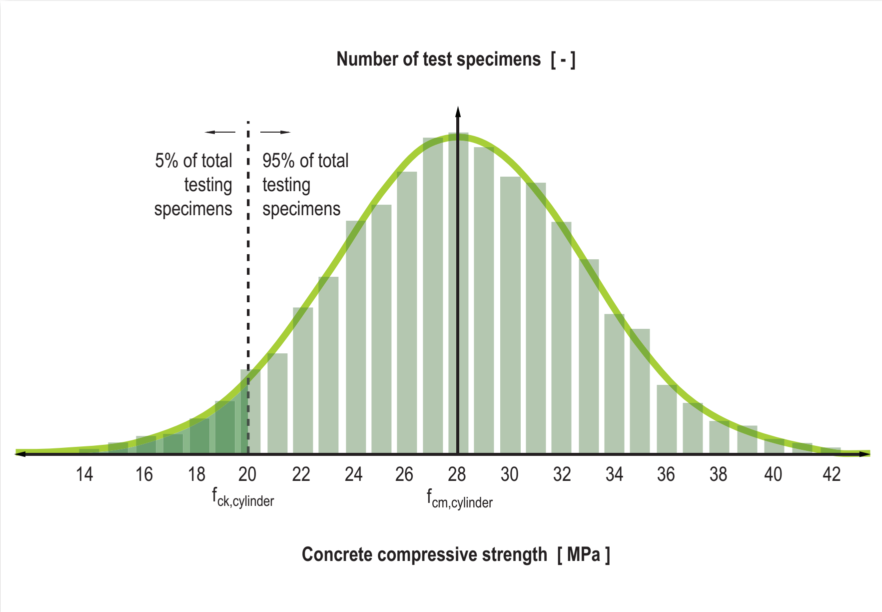


Figure 3: Generic normal distribution of concrete strength

Table 3: Corrosion protection layers

application		strand		duct		duct filler		concrete		layers	*fib*
internal	bonded	bare	0	steel	1	grout	1	cover	1	3	PL 1
				plastic	1+					3+	PL 2 [2], PL 3 [3]
	unbonded	bare	0	steel	1	grease / wax	1	cover	1	3	PL 1
				plastic	1+					3+	PL 2 [2], PL 3 [3]
		monostrand [1]	2	none	0	none	0			3+	–
				steel	1	(filler)	0			4	PL 1
				plastic	1+					4+	PL 2 [2], PL 3 [3]
				steel	1	grout	1			5	PL 1
				plastic	1+					5+	PL 2 [2], PL 3 [3]
external		bare	0	steel	1	grout	1	none	0	2	PL 1
				plastic	1+					2+	PL 2 [2], PL 3 [3]
		bare	0	steel	1	grease / wax	1			2	PL 1
				plastic	1+					2+	PL 2 [2], PL 3 [3]
		monostrand [1]	2	none	0	none	0	none	0	2+	–
				steel	1	(filler)	0			3	PL 1
				plastic	1+					3+	PL 2 [2], PL 3 [3]
				steel	1	grout	1			4	PL 1
				plastic	1+					4+	PL 2 [2], PL 3 [3]

1) Monostrands have two layers of protection (plastic sheathing and wax/grease). 2) Upon watertight test. 3) Upon electrical isolation test.

Ducts

Ducts made of steel or plastic are installed within the structure and create the necessary conduit for the post-tensioning strand tendons to be correctly placed and aligned. Additionally, in case of internal bonded tendons, ducts must also provide adequate bond behavior between the tendon, grout and concrete. In some cases, the duct also contributes to the electrical isolation between the tendon and the structure.

BBR VT Plastic Duct (round)

Corrugated round plastic duct complying with *fib* Bulletin 75, PTI/ASBI M50.3-19 and EAD16 is used for internal CONA CMI, CONA CMF and CONA CMM Single tendons. BBR VT Plastic Ducts (round) are available with nominal internal diameters (d_i) of 23, 50, 60, 75, 85, 100, 115, 130, 145 and 160 mm. This duct uses a unique material melt which permits its use for a wide temperature range, from -20 °C to +50 °C.

BBR VT Plastic Duct (flat)

Corrugated flat plastic duct complying with *fib* Bulletin 75, PTI/ASBI M50.3-19 and EAD16 are used for internal CONA CMI and CONA CMF tendons. BBR VT Plastic Ducts (flat) are available with the following nominal inner dimensions: 38 x 22 mm, 52 x 21 mm, 72 x 21 mm, 76 x 25 mm and 90 x 21 mm. This duct uses a unique material melt which permits its use for a wide temperature range, from -20 °C to +50 °C.

Table 4: Intended use of different ducts with CONA CMX post-tensioning kits

	Corrugated steel duct	Corrugated plastic duct	Smooth steel duct	Smooth plastic duct
CONA CMI	●	●	▲	▲
CONA CME	–	–	●	●
CONA CMF	●	●	▲	▲
CONA CMM (Single)	●	●	▲	▲

● Standard ▲ Standard in unbonded applications. Subject to the regulations in force at the place of use in bonded applications.

Corrugated round steel ducts

Corrugated galvanized or bare steel ducts made from steel strip sheath complying with EN 523 or equivalent standards and regulations in force at the place of use. Corrugated round steel ducts are typically used for internal CONA CMI, CONA CMF and CONA CMM Single tendons and can be made to nearly any diameter. Depending on the duct diameter, the steel strip has a typical thickness of 0.2 - 0.6 mm.

Smooth round steel ducts

Smooth steel ducts may be used for CONA CME external tendons and for special applications, such as internal bonded loops using CONA CMI tendons. Smooth steel ducts according to EN 10255, EN 10216-1, EN 10217-1, EN 10219-1, EN 10305-5 or the standards and regulations in force at the place of use can be used. Smooth round steel ducts are available with a wide range of diameters and wall thicknesses.

Smooth plastic ducts

Smooth plastic ducts, made of UV resistant high density polyethylene (HDPE), complying with EN 12201 or the standards and regulations in force at the place of use are used for external CONA CME tendons. Smooth plastic ducts are typically available with the following outside dimensions (d_o), 45, 63, 90, 110, 125, 140, 160, 180, 200 mm and a wide range of wall thicknesses and pressure ratings.

Corrugated flat steel ducts

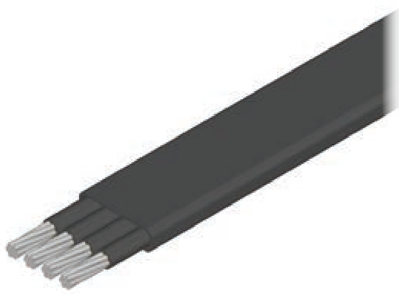
Flat ducts may be used for tendons with 2 to 6 strands in accordance with EN 523 or the standards and regulations in force at the place of use. Flat ducts are commonly used for internal bonded CONA CMI and CONA CMF tendons. Flat corrugated ducts are available with a wide range of dimensions.

Smooth flat steel ducts

Flat smooth steel ducts may also be used if permitted at the place of use.

Additional smooth plastic sheathing

Grouped and sheathed monostrands with an additional smooth rectangular plastic sheathing are used for CONA CMB tendons. For further details on the material and dimensional properties of the sheathed band tendons, please either refer to the relevant ETA document or contact your local BBR Network Member.



BBR VT CONA CMX grout to latest European Standards

Grout plays a key role in the performance and durability of post-tensioning tendons. BBR VT CONA CMX grout not only provides the necessary bond between the strands and structural member, but also ensures excellent corrosion protection for the prestressing steel. In 2007, and again in 2016, BBR devised and held a comprehensive grouting seminar where all BBR Post-Tensioning Specialists were fully trained on the latest European Standards relating to grouting requirements, procedures and test methods. Since then, BBR Network Members have adopted the new standards and are continuously educated and annually audited by the ETA Holder.

European Standards EN 447, 446 and 445

The latest European grouting standards are:

- EN 447: Basic requirements for grout for prestressing tendons
- EN 446: Grouting procedures
- EN 445: Test methods

These provide the basic requirements for the approval of cement grout in compliance with EN 1992, Eurocode 2: Design of concrete structures, prEN 13670: Execution of concrete structures and EAD16: Post-tensioning kits for prestressing of structures.

Testing regime

The testing regime includes three levels:

- Initial type and audit testing in accordance with EN 447
- Suitability testing for a specific project in accordance with EN 446
- Inspection during grouting works on a specific project in accordance with EN 446

The test methods are prescribed in EN 445.

Properties of grout

Testing of grout will be performed to EN 445 standard including:

- Sieve test – homogeneity
- Cone method or grout spread – fluidity
- Wick induced or inclined tube – bleeding
- Wick induced – volume change
- Broken halves of prisms – compressive strength
- Setting time
- Density

BBR VT CONA CMX grout mixtures and equipment

BBR VT CONA CMX grout mixtures are homogenous mixtures of cement, water and admixtures. Grouting equipment comprises a mixer, pump and necessary connection hoses, valves and measuring devices. Grout mixtures, properties and procedures provided by BBR Post-Tensioning Specialists fulfill the latest European Standards. All BBR Network Members employ qualified and trained personnel in grouting and use only prime materials, as well as leading equipment, to produce excellent grout. Furthermore, BBR VT CONA CMX grout is assessed and certified by an independent Notified Body.

Filling material

Cement grout

Cement grout is alkaline and provides a passive environment around strands. Cement grouts typically observe standards EN 445, EN 446, EN 447 or alternatively standards and regulations in force at the place of use. EAD16 recommends the following properties for cement grout materials:

- less than 0.3% bleeding and air void in inclined tube test;
- no significant cracking visible to the naked eye in inclined test;
- less than 10% sedimentation expressed as variation of density;
- less than 0.3% wick-induced bleeding.

Grease

Grease according to EAD16 or the equivalent standards and regulations in force at the place of use may be used as filling material for unbonded applications. EAD16 recommends amongst others the following properties for grease material:

- dropping point has to be higher than 150 °C;
- after 72 hours at 40 °C less than 2.5% oil separation and after 7 days at 40 °C less than 4.5% oil separation;
- no corrosion after 168 hours at 35 °C.

Wax

Wax according to EAD16 or the equivalent standards and regulations in force at the place of use may be used as filling material for unbonded applications. EAD16 recommends amongst others the following properties for grease material:

- congealing point higher than 65 °C;
- no cracks at penetration at 20 °C;
- less than 0.5% bleeding at 40 °C.

Circulating dry air

Actively circulating dry air allows for corrosion protection of the tendons provided that a permanent monitoring of the drying and circulating system is in place. This is, in general, only applicable to structures of particular importance.

The respective standards and regulations in force at the place of use must be observed.

Reinforcement steel

Reinforcement steel is an integral part of the post-tensioning kit and is used to control the crack width in the anchorage zone according to prEN 10080, included in EAD16, therefore this steel has to fulfill the following:

Yield strength	f_{pp}	500 MPa
Ultimate/yield strength ratio	f_{max} / f_{pp}	1.08
Total elongation at max. force A_{gt}	ε_u	5%

Table 5: Typical reinforcement steel material properties to prEN 10080

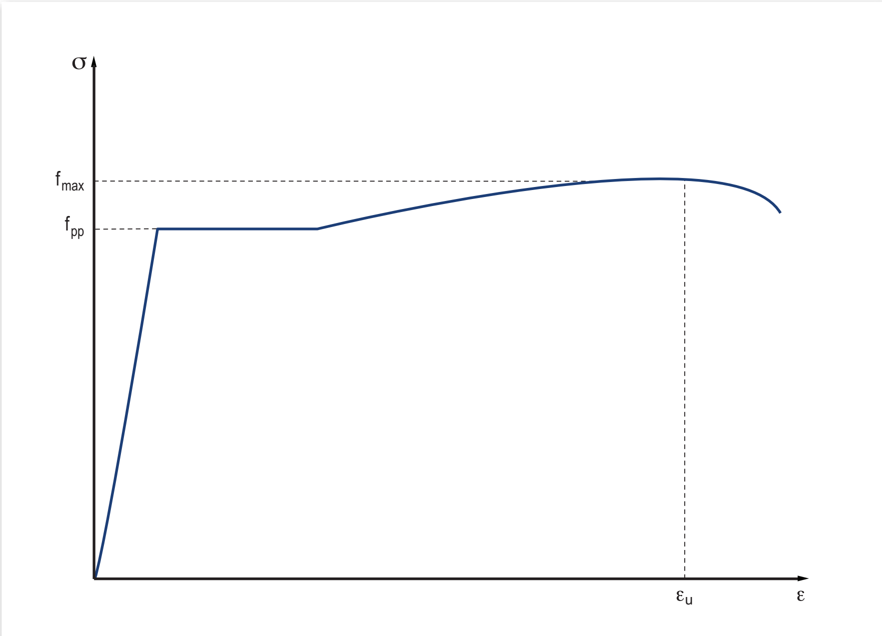


Figure 4: Stress-stain diagram of reinforcement steel

Technical detailing

Prestressing forces

Although it depends on the standard used, it is widely accepted that the yield point is defined as the point of an irreversible plastic strain of 0.1%. In this case, the stress at the yield point is identified with $f_{p0,1}$. As shown in Figure 5, the limit of proportionality, f_{pp}, is lower and is usually determined as the stress with an irreversible plastic strain of 0.01%. Also shown in the figure are the maximum overstressing force, $0.95 \cdot f_{p0,1}$, and the maximum prestressing force in terms of the yield stress, $0.9 \cdot f_{p0,1}$, and in terms of the maximum characteristic tensile strength, $0.8 \cdot f_{pk}$ according to the Eurocodes. Prestressing forces may depend on regulations in force at place of use.

Table 6: Typical strand characteristic and yield strengths

	MPa		
f_{pk}	1,770	1,820	1,860
$f_{p0.1}$	≈ 1,560	≈ 1,600	≈ 1,640

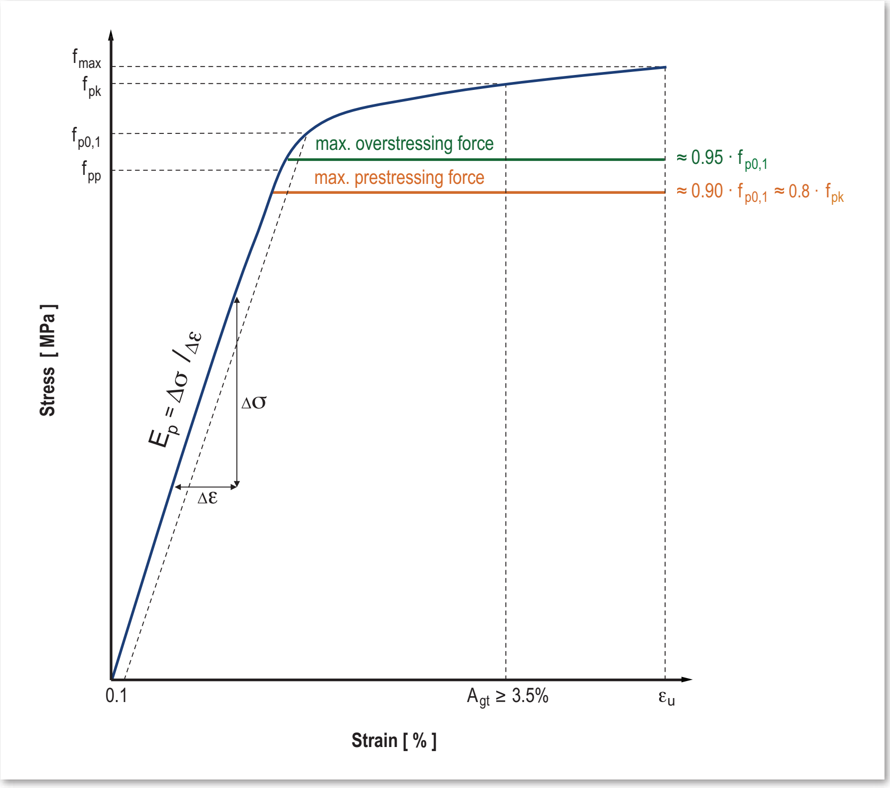


Figure 5: Stress-strain diagram of prestressing steel and relevant stress levels

The following tables show the maximum prestressing force, the maximum overstressing force and typical prestressing forces according to various standards, for different strand and tendon sizes.

Forces for strands with a tensile strength equal to 1,770 MPa might be obtained from the values in Tables 7 and 8 and reduced by the factor $f_R = 0.952$.

$$F_{p0,1\text{-}1770} = F_{p0,1\text{-}1860} \cdot f_R$$

Table 7: Prestressing forces for strand ***05*-100** 1,860

	Max. prestressing force		Max. prestressing force	Max. overstressing force	Characteristic value of max. force
	SIA	DIN	EN		
	Swiss Standards	German Standards	European Standards		
	$0.70 \cdot F_{pk} \approx 0.80 \cdot F_{p0.1}$	$0.85 \cdot F_{p0.1} \approx 0.75 \cdot F_{pk}$	$0.90 \cdot F_{p0.1} \approx 0.80 \cdot F_{pk}$	$0.95 \cdot F_{p0.1} \approx 0.85 \cdot F_{pk}$	F_{pk}
n *05* 1) Number of strands	kN				
01 *05*	130	140	148	156	186
02 *05*	260	279	295	312	372
03 *05*	391	418	443	467	558
04 *05*	521	558	590	623	744
07 *05*	911	976	1,033	1,091	1,302
12 *05*	1,562	1,673	1,771	1,870	2,232
19 *05*	2,474	2,649	2,804	2,960	3,534
31 *05*	4,036	4,321	4,576	4,830	5,766

Table 8: Prestressing forces for strand **06-150** 1,860

	Max. prestressing force				Max. prestressing force		Max. overstressing force		Characteristic value of max. force	
	SIA		DIN		EN					
	$0.70 \cdot F_{pk} \approx 0.80 \cdot F_{p0.1}$		$0.85 \cdot F_{p0.1} \approx 0.75 \cdot F_{pk}$		$0.90 \cdot F_{p0.1} \approx 0.80 \cdot F_{pk}$		$0.95 \cdot F_{p0.1} \approx 0.85 \cdot F_{pk}$		F_{pk}	
Designation	n06-140	n06-150	n06-140	n06-150	n06-140	n06-150	n06-140	n06-150	n06-140	n06-150
n 06 1) Number of strands	kN									
01 06	182	195	195	209	206	221	218	234	260	279
02 06	364	391	389	418	412	443	435	467	520	558
03 06	546	586	584	627	618	664	653	701	780	837
04 06	728	781	779	836	824	886	870	935	1,040	1,116
05 06	910	977	973	1,046	1,031	1,107	1,088	1,169	1,300	1,395
06 06	1,092	1,172	1,168	1,255	1,237	1,328	1,305	1,402	1,560	1,674
07 06	1,274	1,367	1,363	1,464	1,443	1,550	1,523	1,636	1,820	1,953
08 06	1,456	1,562	1,557	1,673	1,649	1,771	1,740	1,870	2,080	2,232
09 06	1,638	1,758	1,752	1,882	1,855	1,993	1,958	2,103	2,340	2,511
12 06	2,184	2,344	2,336	2,509	2,473	2,657	2,611	2,804	3,120	3,348
13 06	2,366	2,539	2,530	2,718	2,679	2,878	2,828	3,038	3,380	3,627
15 06	2,730	2,930	2,920	3,137	3,092	3,321	3,263	3,506	3,900	4,185
16 06	2,912	3,125	3,114	3,346	3,298	3,542	3,481	3,739	4,160	4,464
19 06	3,458	3,711	3,698	3,973	3,916	4,207	4,133	4,440	4,940	5,301
22 06	4,004	4,297	4,282	4,600	4,534	4,871	4,786	5,141	5,720	6,138
24 06	4,368	4,687	4,672	5,018	4,946	5,314	5,221	5,609	6,240	6,696
25 06	4,550	4,883	4,866	5,228	5,153	5,535	5,439	5,843	6,500	6,975
27 06	4,914	5,273	5,256	5,646	5,565	5,978	5,874	6,310	7,020	7,533
31 06	5,642	6,054	6,034	6,482	6,389	6,863	6,744	7,245	8,060	8,649
37 06	6,734	7,226	7,202	7,737	7,626	8,192	8,049	8,647	9,620	10,323
42 06	7,644	8,203	8,175	8,782	8,656	9,299	9,137	9,815	10,920	11,718
43 06	7,826	8,398	8,370	8,991	8,862	9,520	9,355	10,049	11,180	11,997
48 06	8,736	9,374	9,343	10,037	9,893	10,627	10,442	11,218	12,480	13,392
55 06	10,010	10,742	10,706	11,501	11,336	12,177	11,965	12,854	14,300	15,345
61 06	11,102	11,913	11,874	12,755	12,572	13,505	13,271	14,256	15,860	17,019
69 06	12,558	13,476	13,431	14,428	14,221	15,277	15,011	16,125	17,940	19,251
73 06	13,286	14,257	14,209	15,264	15,045	16,162	15,882	17,060	18,980	20,367

1) see Table 2 for strand specification. Prestressing forces vary according to place of use.

Prestress loss

Prestress force is applied to the post-tensioning tendon from the stressing end. Due to the different types of prestress losses – instantaneous and long term – the prestress force in the tendon varies from point-to-point, as well as throughout the life of the structure.

Instantaneous losses

Instantaneous losses are mainly caused by friction between the tendon and the interior of the duct, slip at anchorages and couplers and elastic deformation of the concrete.

Friction losses

The intended angular deviation of the strand and the unintentional wobble of the tendon create friction between the strands and the duct, see Figure 6. In particular, when the tendon is stressed from one end, due to the curved tendon layout, the strands will press on the inside of the curve reducing the stressing force. In addition, unintended wobble further decreases the prestressing force of the tendon. Both friction sources might be evaluated according to Coulomb's law, which leads to the following equation:

$$F_x = F_0 \cdot e^{-(\mu \cdot \alpha + k \cdot x)}$$

Where F_x is the prestressing force at a distance x along the tendon, F_0 is the prestressing force at x = 0 m, μ is the friction coefficient, k is the wobble coefficient, **α** is the sum of angular displacements over distance x irrespective of direction or sign and x is the distance along the tendon from the point where the prestressing force is equal to F_0. The formula above is demonstrated in Figure 6. Table 9 shows recommended values of the friction and wobble coefficient applicable for the various CONA CMX strand post-tensioning kits.

Typically American Standards evaluate friction losses by the following similar equation:

$$F_x = F_0 \cdot e^{-(\mu \cdot \alpha + k_{as} \cdot x)}$$

Where k_{as} is an equivalent wobble coefficient which may be related to k with

$$k_{as} = \mu \cdot k$$

Slip at anchorages and couplers

During load transfer from the stressing jack to the anchorage, part of the initial load is lost due to slippage at the anchorage. This effectively results in a shortening of the strand which leads to an instantaneous loss of prestress. In general, slip at stressing and fixed anchorages and at fixed couplers is 6 mm. It should be noted that slip at movable couplers is twice this amount. The loss of force resulting from wedge draw-in can be partially compensated by pre-seating the wedges. Wedge draw-in can be limited to 4 mm at the stressing anchorage and at the first construction stage if each wedge is pre-seated with an approximate force of 25 kN.

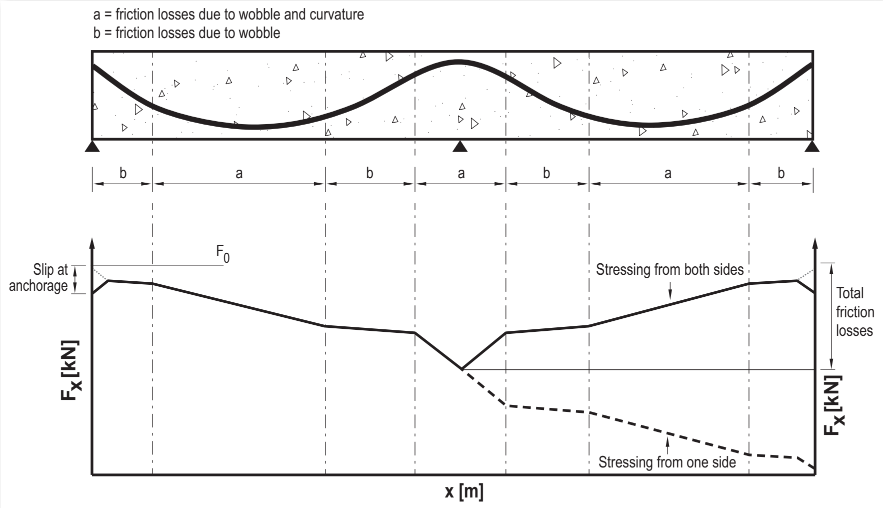


Figure 6: Concept of instantaneous losses

Elastic shortening of concrete

When the force of the tendon is transferred to the concrete, the concrete member shortens and simultaneously the post-tensioning tendon shortens by the same amount. Elastic shortening loss may be evaluated by strain compatibility, i.e. the decrease of strain in the tendon is equal to the final elastic strain in the concrete due to the load transfer. Compatibility assumption leads to the following expression:

$$\Delta F_p = F_0 \cdot \frac{E_p \cdot A_p}{E_p \cdot A_p + E_c \cdot A_c}$$

Where E_p, A_p and E_c, A_c are the modulus of elasticity and area of the prestressing steel and concrete respectively. The above expression cannot be used for tendons stretched sequentially.

Long term losses

Long term losses are primarily caused by relaxation of the prestressing steel and creep and shrinkage of the concrete. Shrinkage and creep modify the length of concrete elements over time. These changes in length are followed by changes in the length of the prestressing tendons, leading to a loss of the prestress force.

Shrinkage of concrete is the volume reduction that concrete experiences when exposed to a lower relative humidity environment. Creep of concrete is the time-dependent strain which takes place after the action of constant stress over time. On the other hand, the effect called relaxation is the counterpart of creep in which, under sustained strain, the material exhibits a reduction in the stress level. Both, creep of concrete and relaxation of prestressing steel strand happen over time in post-tensioned structures.

Table 9: Typical strand friction parameters

Type of duct	Recommended values		Range of values	
		k		k
	rad $^{-1}$	rad/m	rad $^{-1}$	rad/m
Corrugated steel duct	0.18	0.005	0.17 - 0.19	0.004 - 0.007
Smooth steel duct	0.18		0.16 - 0.24	
Corrugated platic duct	0.12		0.10 - 0.14	
Smooth plastic duct	0.12		0.10 - 0.14	
Monostrand (greased/waxed)	0.06	0.009	0.05 - 0.07	0.004 - 0.010

Degree of filling, center of gravity and eccentricity

The degree of filling (f) gives the ratio of the inner area of the duct which is occupied by the prestressing steel. Accordingly, the degree of filling is defined as:

$$f = \frac{\text{cross-sectional area of prestressing steel}}{\text{cross-sectional area of inner diameter of duct}}$$

Thus, low degree of filling values are indicative of a relatively loose installation of the strands, see (b) in Figure 7, while higher degree of filling values are indicative of a tighter strand scenario, see (a) in Figure 7.

Typical degrees of filling values for round ducts are in the range of 0.35 to 0.50. However, in particular cases with a reduced minimum radius of curvature (for example loop tendons), smaller degree of filling values (f ~ 0.25-0.30) might be used to facilitate the tendon installation.

In the particular case of low degrees of filling, the center of gravity of the strand bundle (G.C.S.) might lead to a considerable distance from the center of gravity of the duct (G.C.D.). This distance or eccentricity (e), might be considered during the design stage, as it might have a noticeable effect on the overall stability of the structure.

The graphs in Figure 8 show the vertical eccentricity of post-tensioning tendons within the round duct for tendon sizes between 1 to 31 for *05* strands and 1 to 73 for 06 strands respectively.

Degrees of filling are equal to 0.25, 0.35, 0.40 and 0.45. For exact eccentricity values and common duct sizes, refer to tables in the Technical Data section.

In the case of flat ducts with a single row of strands, see (c) in Figure 7, eccentricity may be evaluated with the following expression:

$$e = \frac{1}{2} \cdot (d_i - d)$$

Where d_i is the inner duct diameter and d is the diameter of the prestressing strand. However, the eccentricity of a flat duct is comparably small.

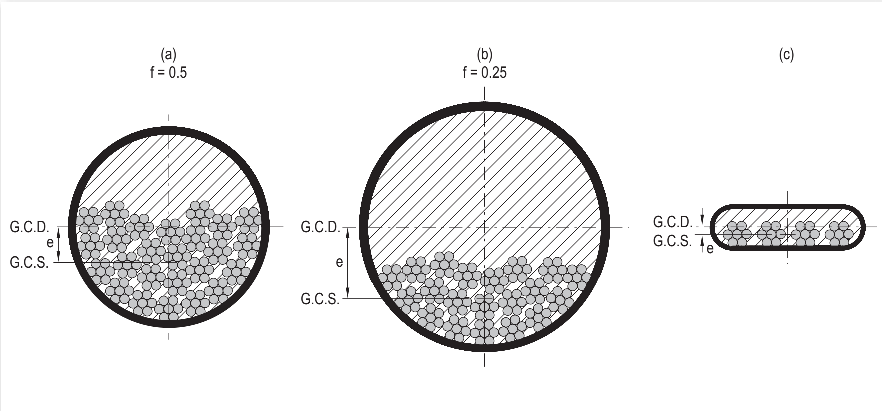


Figure 7: Center of gravity by high (a) and low (b) degree of filling of round ducts and flat duct (c)

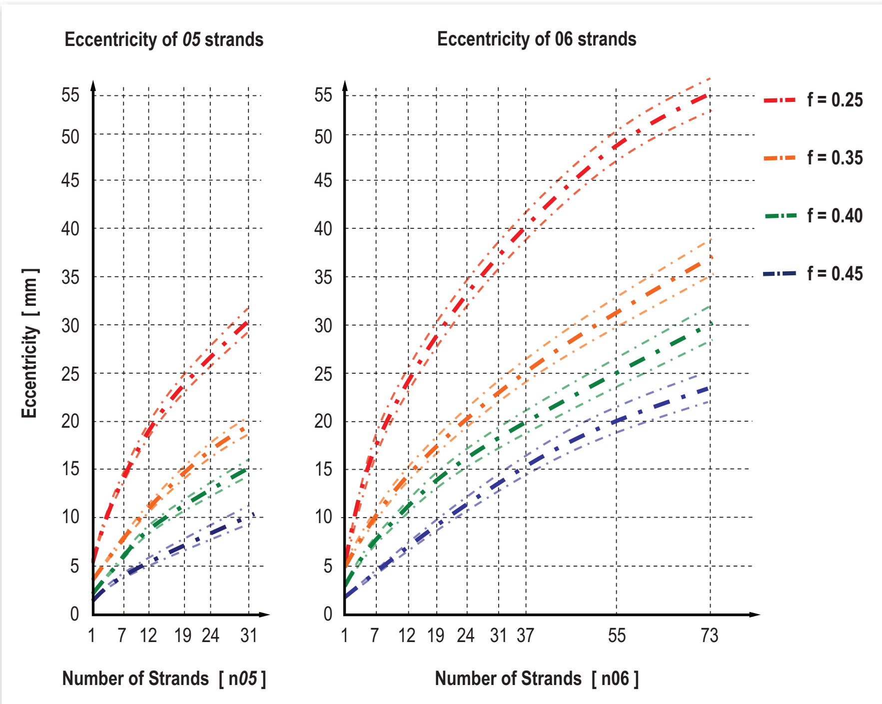


Figure 8: Eccentricity of *05* and 06 strands in a round duct

Minimum radii of curvature

Practical experience and analytical models have shown that the contact pressure between strands and duct and between duct and concrete increases, in a linear fashion, with the local curvature of the post-tensioning tendon. Thus, the minimum radius of curvature of a tendon, R_{min}, can be expressed in terms of the prestressing force of the tendon, $F_{pm,0}$, the diameter of the strand, (e.g. d = 15.7 mm), the inner duct diameter, d_i, and the recommended allowable contact pressure, $p_{R,max}$, using the following equation:

$$R_{min} = \frac{2 \cdot F_{pm,0} \cdot d}{d_i \cdot p_{R,max}} > R_b$$

R_b is a limiting minimum radius of curvature, to avoid yield due to bending of the strands.

Table 10: Limiting radius of curvature for *05* and 06 strands

Type of strands	R_b
	m
05	1.7
06	2.0

Where the stable factor (K_f) is known precisely – as, for example, with CONA CMB tendons – then the following equation can be used to obtain the minimum radius of curvature:

$$R_{min} = \frac{F_{pm,0} \cdot K_f}{n \cdot p_{R,max}}$$

where n is the number of strands in the tendon and K_f the number of strands laying on top of each other (see Figure 9).

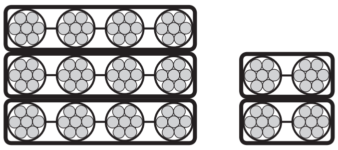


Figure 9: K_f factors in different strand configurations

Depending on the concrete strength at the time of stressing, additional reinforcement for splitting forces may be required in the areas of reduced minimum radius of curvature. Standards and regulations on minimum radius of curvature or allowable contact pressure under the prestressing strands applicable at the place of use must be complied with.

Typical recommended values for the allowable contact pressure under the prestressing strands are:

- **$p_{R,max}$ = 140 - 200 kN/m**
  CONA CMI and CONA CMF, internal bonded tendons with corrugated steel or plastic ducts
- **$p_{R,max}$ = 140 - 200 kN/m**
  CONA CMB, external band tendons
- **$p_{R,max}$ = 350 kN/m**
  CONA CME, external tendons with smooth steel or plastic ducts
- **$p_{R,max}$ = 800 kN/m**
  CONA CMI, bonded loop tendons with smooth steel ducts

Tables of minimum radius of curvature have been pre-calculated and are presented in the Technical Data section for each system. The values have been calculated assuming a prestressing force of $0.85 \cdot F_{p0,1}$. Therefore the given values are conservative and can be applied for other strand types and prestressing forces. For strands with tensile strength f_{pk} = 1,770 MPa the values for the inner duct diameter (d_i) and the eccentricity (e) remain constant. The minimum radius (R_{min}) in these tables can be reduced by the factor f_R = 0.952 with the following equation:

$$R_{min,1770} = f_R \cdot R_{min,1860} \geq R_b$$

Minimum straight length after the anchorage

At the anchorages and couplers, the tendon layout should generally provide a minimum straight section beyond the end of the trumpet, see Figure 10. In the case of continuous tendons, in which the degree of filling is $0.35 \leq f \leq 0.50$ and with a minimum or reduced radius of curvature after the trumpet, the minimum straight length must be:

$L_{min} = 5 \cdot d_i \geq 250\text{mm}$

On the other hand, for continuous tendons with smaller degrees of filling $0.25 \leq f \leq 0.30$, the minimum straight length must be:

$L_{min} = 8 \cdot d_i \geq 400\text{mm}$

d_i = internal duct diameter

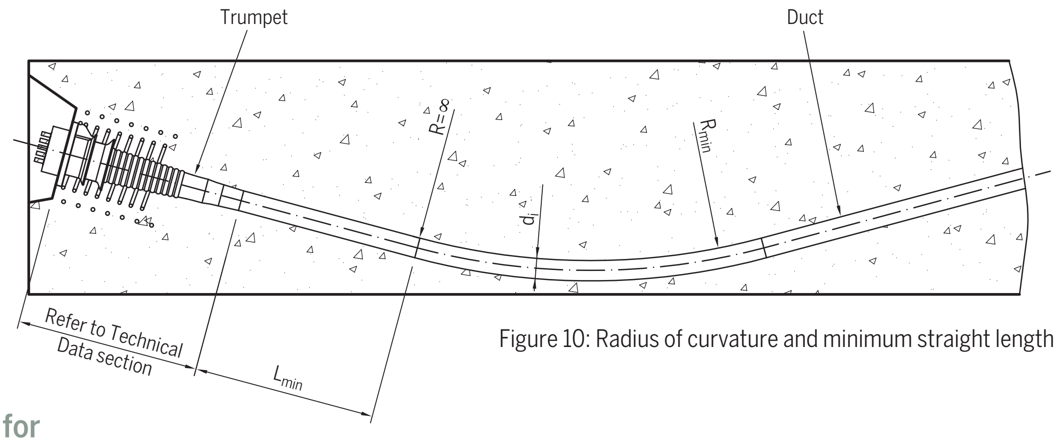


Figure 10: Radius of curvature and minimum straight length

Deviators and saddles for external post-tensioning

The deviator, see Figure 11, has to transfer the transversal forces (radial to the deviator) and longitudinal forces (tangential to the deviator) generated by a deviated external tendon to the structure. Moreover, deviators have to provide a smooth surface for the tendon. The deviator can be made of steel, HDPE or equivalent in respect to the structural and surface requirements.

To avoid any kinking of the tendon it is recommended, that an additional deviation ($\Delta\alpha$) of 3° with $R_2 < R_{min}$, is provided as shown in Figure 11.

For grouting or filling of the ducts with grease or wax, vents must be provided or vacuum grouting must be applied.

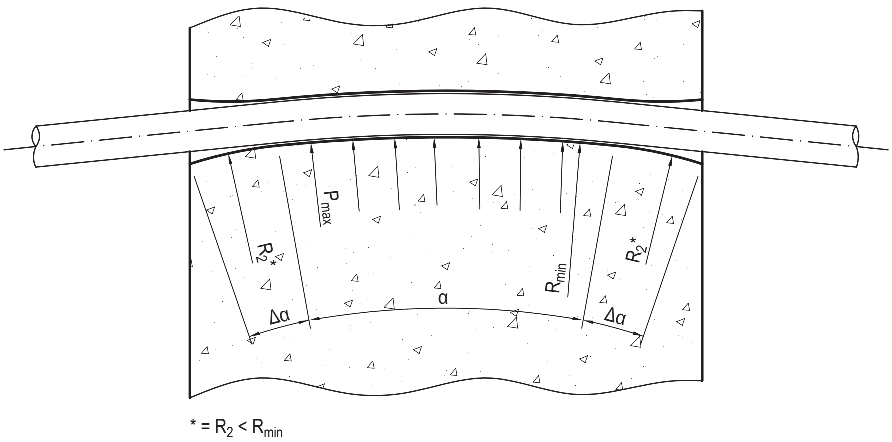


Figure 11: Minimum radius of curvature in deviators and saddles

Support of tendons

In order to ensure the correct tendon profile and to prevent flotation, displacement due to concreting or disconnections due to impacts, tendon supports need to be provided at regularly spaced intervals, see Figure 12. Generally, the spacing of the supports needs to be between 1.0 to 1.8 m although this may need to be reduced in certain locations:

- Spacing of 0.8 m in the region of maximum tendon curvature.
- Spacing of 0.6 m whenever the minimum radius of curvature is less than 4.0 m.

Note that an improperly secured duct might lead to excessive tendon wobble and therefore a higher friction loss. Additionally, excessive wobble or inadequate duct alignment might complicate or even impede the tendon installation.

For electrically isolated tendons, depending on the regulations at the place of use, the plastic duct may be supported by an additional sheathing at the regions of maximum tendon curvature.

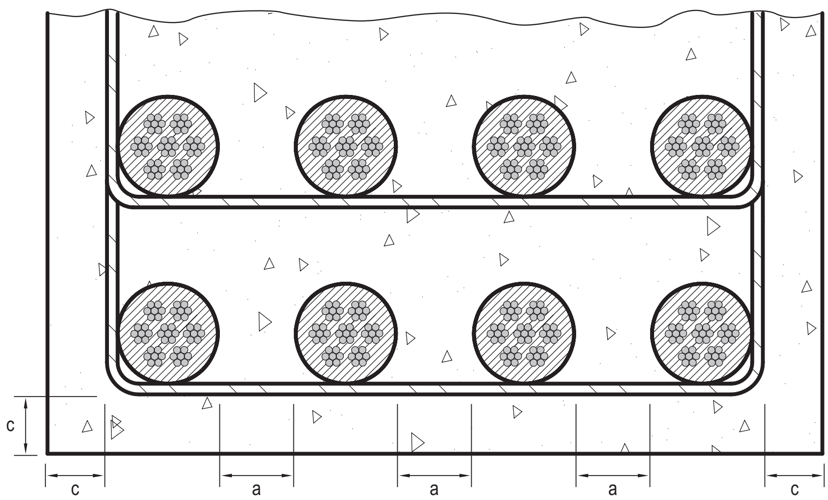


Figure 12: Tendon support on reinforcement and tendon layout

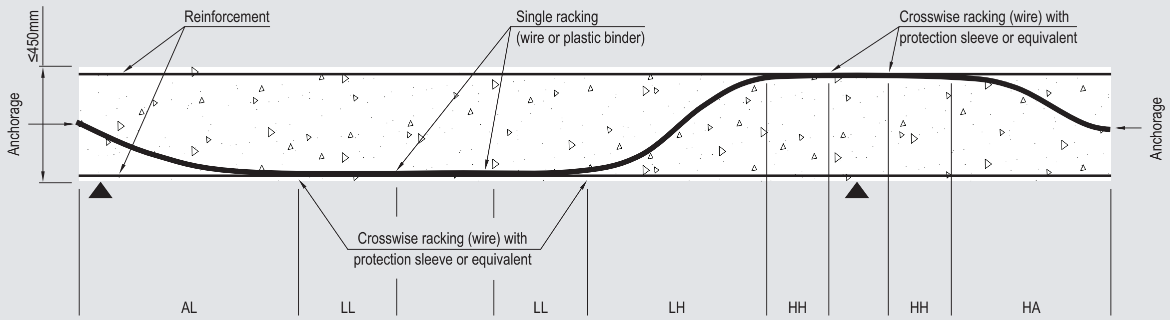
Tendon layout

The layout of the tendons in the general zone is shown in Figure 12. The following distances have to be obeyed:

- concrete cover, c;
- distance a, bigger than the maximum gravel diameter and sufficient space for vibrating concrete.

Free tendon layout with the CONA CMM Single and Two/Four monostrand system

The free tendon layout technique for unbonded applications such as the CONA CMM Single and Two/Four monostrand system was established in Austria and offers a significant time and cost optimization. Cost reductions of 20% have been achieved. This innovative method allows placement of tendons without any tendon supports in slabs with a thickness of smaller than 450 mm. One of the key benefits of the free tendon layout method is that the tendon is only fixed on two high points to the upper reinforcement over supporting columns or walls. At midspan, the tendon is located on the lower reinforcement. No chairs are required between the high and low point. The vertical profile of the tendon was investigated in detail and a parabolic drape was observed.



Sections		Max. distances of fixing points
AL	Anchorage to Low point	3.0 m
LL	Low point to Low point	1.0 m - 1.3 m
LH	Low point to High point	3.0 m
HH	High point to High point	0.3m - 1.0 m
HA	High point to Anchorage	1.5 m

Anchor zone design

Concrete strength at the time of stressing

At the time of stressing, the mean concrete compressive strength ($f_{cm,0}$) must be at least the value given in the working tables, as shown in the Technial Data section or European Technical Assessments of the respective CONA CMX strand post-tensioning kit. The concrete test specimen must also be subjected to the same curing conditions as the structure. Table 11 shows the minimum concrete compressive strength at the time of stressing – cylindrical and cubic – applicable for the various CONA CMX post-tensioning kits. Application of the full post-tensioning load is possible at much lower concrete strengths than a traditional single bearing plate configuration through use of the proprietary CONA CMI BT anchorage.

Table 11: Minimum concrete strength

	$f_{cm,cylinder}$	$f_{cm,cube}$
	MPa	
CONA CMI	≥ 19	≥ 23
CONA CME	≥ 19	≥ 23
CONA CMF	≥ 17	≥ 21
CONA CMM	≥ 18	≥ 22
CONA CMB	≥ 29	≥ 35

Partial initial prestressing

For partial initial prestressing with 30 % of the full prestressing force the actual mean value of the concrete compressive strength must be at least $0.5 \cdot f_{cm,0,cube}$ or $0.5 \cdot f_{cm,0,cylinder}$. (See Figure 13).

Local zone reinforcement

Figure 14 shows a comparison of the typical longitudinal and transverse stress distributions between a traditional single bearing plate (CONA CMI SP) anchorage and a CONA CMI BT (Bearing Trumplate) anchorage. At the anchorage, point loading of the concrete leads to compression and bursting stresses in the local zone as the stress field normalises towards the general zone. The CONA CMI BT allows for very small center and edge distances at the anchorage via a proprietary three-plane load transfer which significantly reduces the peak bursting stresses. The Bearing Trumplate (BT) system is available for internal (CMI), external (CME) and flat (CMF) post-tensioning systems.

Confining reinforcement in the form of a helix cage is required in the local zone to resist the bursting stresses, while additional stirrups are specified to aid the helix in reducing crack widths under various loading conditions. Local zone reinforcement is given in the working tables shown in the Technical Data section, or in the European Technical Assessments of the relevant CONA CMX system. While ribbed reinforcing steel grade $R_e > 500$ MPa is specified for all CONA CMX post-tensioning kits, alternative reinforcing steel such as grade $R_e > 460$ MPa may be substituted if appropriate considerations are taken by the respective designer. Reinforcement which exceeds the reinforcement required for the structure may be used as additional reinforcement for the local anchorage zone if appropriate placing is possible.

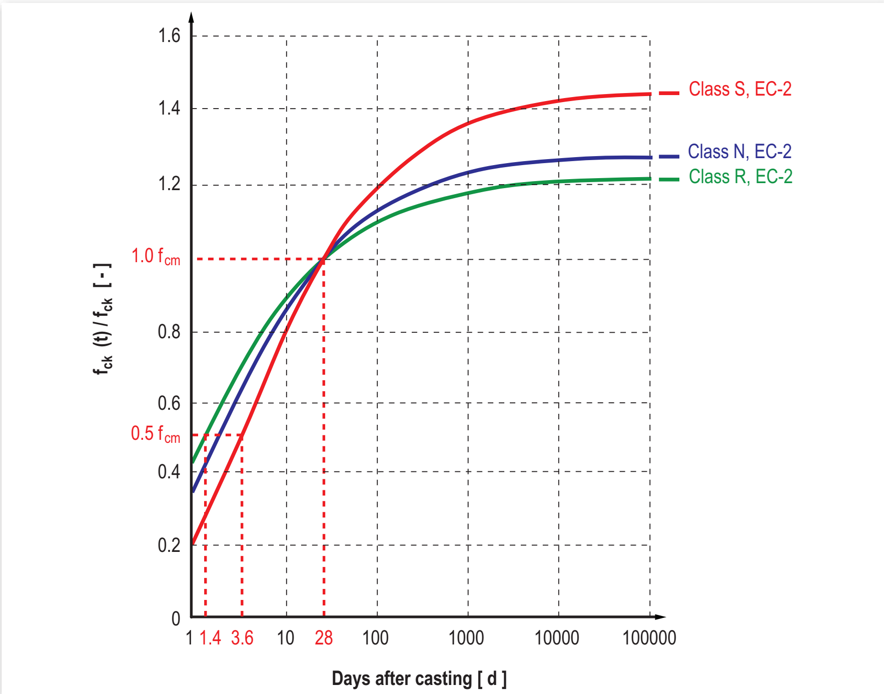


Figure 13: Concrete hardening

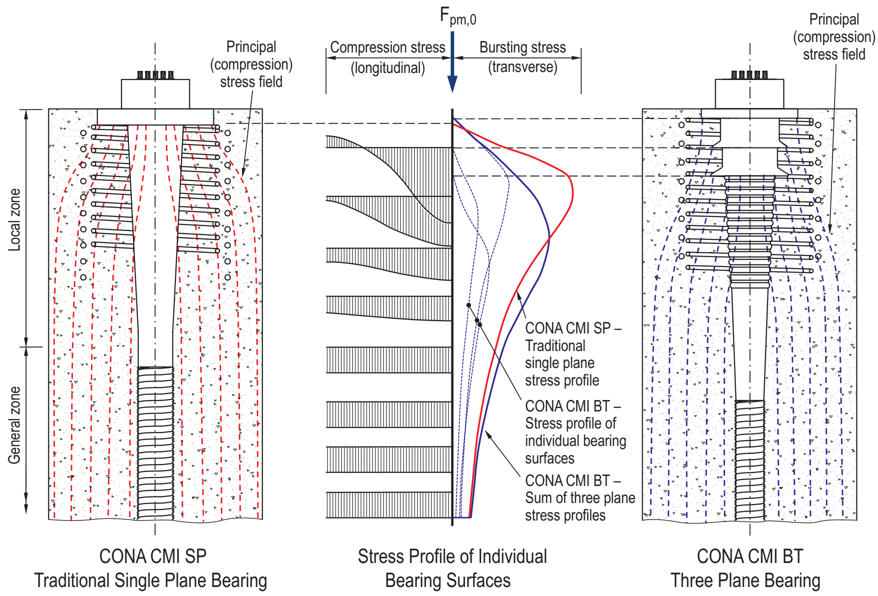


Figure 14: Stress distribution induced in concrete by a prestressing tendon

Center spacing and edge distance

The centre spacing distances, a_c and b_c, and edge distances, a_e and b_e , see Figure 15, between individual anchorages are shown in the working tables in the Technical Data section and the European Technical Assessments of the respective CONA CMX post-tensioning kit or for special applications these can be obtained as datasheets from the ETA Holder, BBR VT International Ltd. In general, these distances must be observed, although a reduction of up to 15% for the centre spacing is permitted provided adjustments to other dimensions are made as follows:

- The reduction should only be applied in one direction, either a_c or b_c, while the counterpart dimension must increase accordingly so that the concrete area, $A_c = a_c \cdot b_c$, remains constant.
- The new reduced center distances, a_c and b_c, should not be less than the outside diameter of the helix and be able to allow a suitable placing of the additional reinforcement, see Figure 15.

Modification of center and edge distances must be made using the following expressions:

$$A_c = a_c \cdot b_c \leq a_{\underline{c}} \cdot b_{\underline{c}}$$

$$b_{\underline{c}} \geq 0.85 b_c \geq OD_{Helix}$$

$$a_{\underline{c}} > \frac{A_c}{b_{\underline{c}}}$$

After the 15% center spacing reduction is applied, the corresponding modified edge distances are:

$$a_{\underline{e}} = \frac{a_{\underline{c}}}{2} - 10 + c \qquad b_{\underline{e}} = \frac{b_{\underline{c}}}{2} - 10 + c$$

where in the latter expression, c refers to concrete cover. Standards and regulations on concrete cover in force at the place of use must be complied with. Should smaller center spacing or edge distances, or different reinforcement steel be needed, please contact your nearest BBR Network Member for further information.

In the case of grouped anchorages, the additional reinforcement of the individual anchorages can be combined, provided appropriate anchorage is ensured.

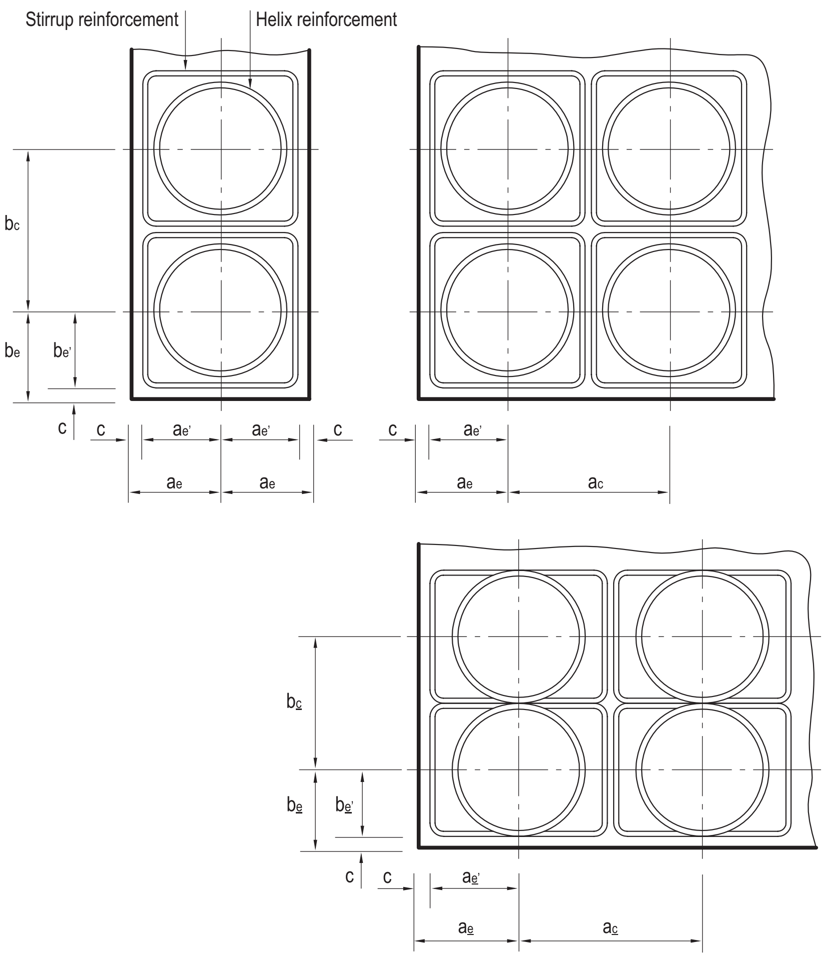
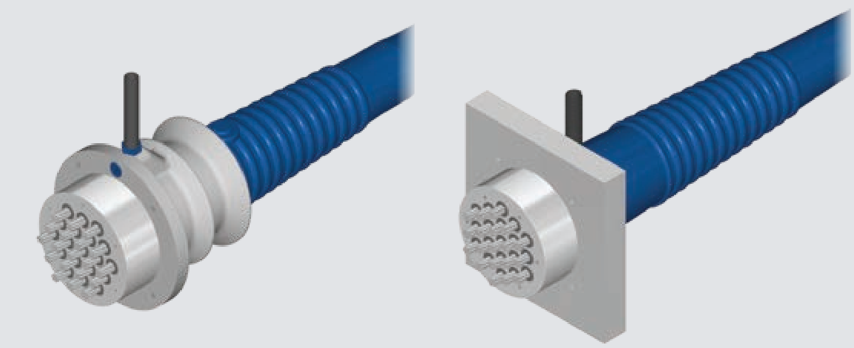


Figure 15: Dimensions of tendon center spacing and edge distance

Efficient detailing with BBR VT CONA CMX

The CONA CMI BT (bearing trumplate) system makes use of an advanced and proprietary three plane load transfer, allowing for very small center and edge distances at the anchorages, as well as application of the full post-tensioning load at very low concrete strengths. The CONA CMI SP (square plate) is a more traditional system with a single plane load transfer to the concrete structure. This also applies for CME and CMF.

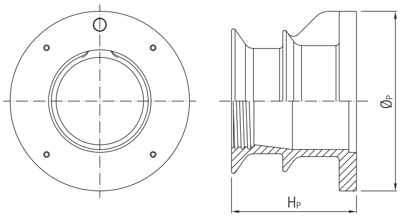


Dimensions and detailing - CONA CMI BT/SP

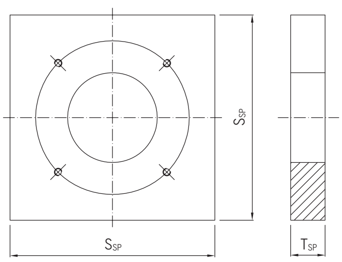
Table 12: CONA CMI component dimensions

Number of Strands				01	02	03	04	05	06	07	08	09	12	13
Bearing Trumplate	Diameter	$Ø_P$	mm	–	130	130	130	170	170	170	195	225	225	240
	Height	H_P	mm	–	120	120	120	128	128	128	133	150	150	160
Square Plate [1]	Side length	S_{SP}	mm	80	140	145	155	185	190	205	225	255	265	285
	Height	T_{SP}	mm	20	20	20	25	30	35	35	35	35	35	40
Anchor Head	Nominal diameter	$Ø_A$	mm	50	90	100	100	130	130	130	150	160	160	180
	Height head A1-A4	H_A	mm	50	50	50	50	50	55	55	60	60	65	72
	Height head A5-A8		mm	65	65	65	65	65	65	65	65	65	70	72
Coupler head type K	Diameter	$Ø_K$	mm	–	185	185	185	205	205	205	240	240	240	290
	Height	H_K	mm	–	85	85	85	85	85	85	90	90	90	90
Coupler head type H	Nominal diameter	$Ø_{AH}$	mm	50	90	95	100	130	130	130	150	160	160	180
	Height head H1	H_{AH}	mm	50	50	50	55	55	60	65	65	70	80	80
	Height head H2		mm	65	65	65	65	65	65	65	65	70	80	80
Coupler sleeve type H	Diameter	$Ø_H$	mm	69	111	121	130	160	164	167	189	200	210	230
	Length sleeve	L_H	mm	180	180	180	180	180	190	200	200	210	230	230
Assemblies	BT anchorage	$L_{A,BT}$	mm	–	296	296	296	432	432	432	721	738	623	819
	SP anchorage	$L_{A,SP}$	mm	–	441	441	446	431	436	436	690	774	774	834
	Coupler K	L_{FK}	mm	–	555	555	555	725	725	725	935	935	820	980
	Coupler H	L_{FH}	mm	–	650	650	650	820	830	840	1,045	1,055	960	1,120

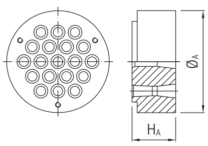
1) Square plate dimensions may be optimised depending on the strength of concrete at transfer. Please contact your nearest BBR representative or refer to the CONA CMI ETA document.



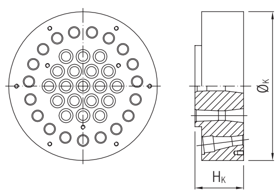
Bearing trumplate



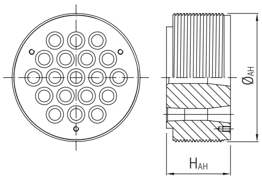
Square plate



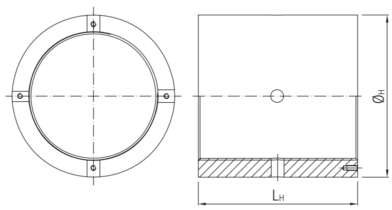
Anchor head



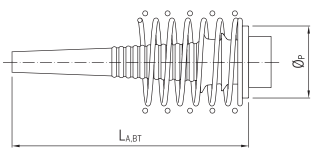
Coupler head type K



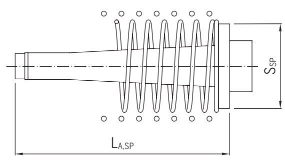
Coupler head type H



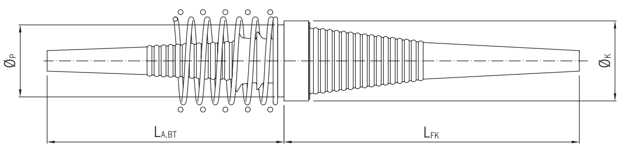
Coupler sleeve type H



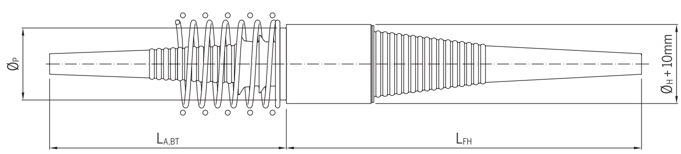
CMI BT Anchorage assembly



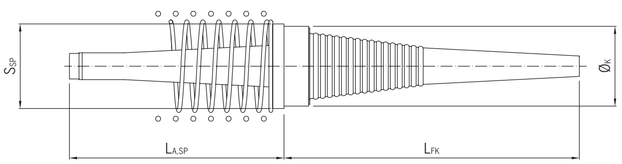
CMI SP Anchorage assembly



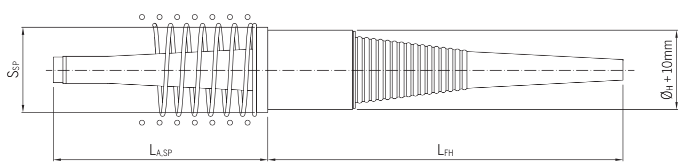
CMI BT Coupler K assembly



CMI BT Coupler H assembly

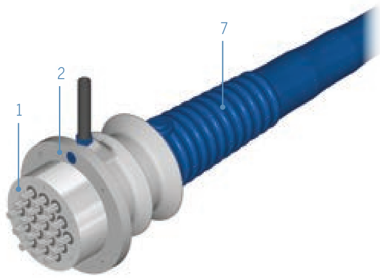


CMI SP Coupler K assembly

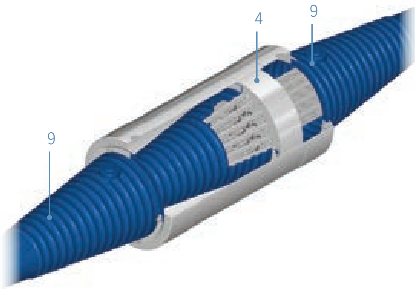


CMI SP Coupler H assembly

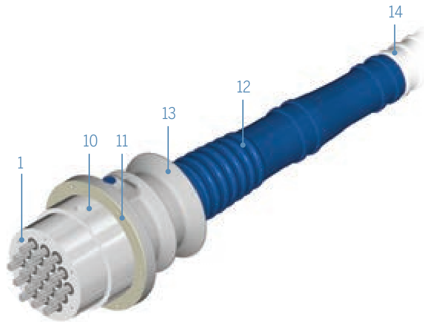
15	16	19	22	24	25	27	31	37	42	43	48	55	61	69	73	91
280	280	280	310	325	360	360	360	400	425	485	485	485	520			
195	195	195	206	227	250	250	250	275	290	340	340	340	350			
320	330	340	370	390	405	415	440	480	510	520	550	595	620			
45	45	50	55	55	60	65	60	70	70	75	80	90	90			
200	200	200	225	240	255	255	255	285	300	320	325	335	365			
75	80	85	95	100	100	105	110	–	–	–	–	–	–			
75	80	85	95	100	100	105	110	120	130	130	140	150	155			
290	290	290	310	340	390	390	390	–	–	–	–	–	–			
90	95	95	105	120	125	125	130	–	–	–	–	–	–		on request	
200	200	200	225	240	255	255	255	285	300	320	325	335	365			
80	85	95	100	100	100	105	115	–	–	–	–	–	–			
80	85	95	100	100	100	105	115	125	135	135	145	160	160			
256	256	266	293	309	324	327	335	370	392	410	422	440	472			
240	250	270	270	280	280	300	320	340	360	360	380	410	410			
854	854	739	886	1,063	1,086	1,086	971	1,295	1,310	1,538	1,538	1,418	1,594			
939	939	944	1,072	1,251	1,210	1,215	1,210	1,340	1,385	1,581	1,586	1,596	1,772			
980	985	870	945	1,210	1,390	1,390	1,280	–	–	–	–	–	–			
1,130	1,140	1,045	1,110	1,370	1,545	1,565	1,470	on request								



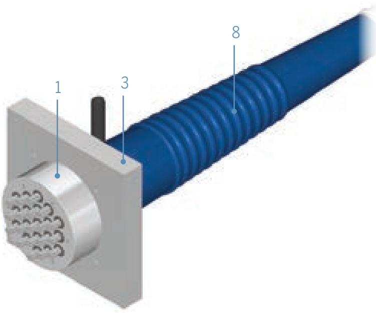
CONA CMI BT Anchorage



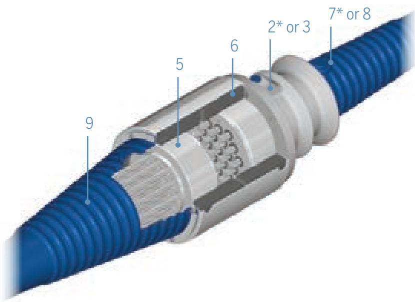
CONA CMI Movable Coupler K



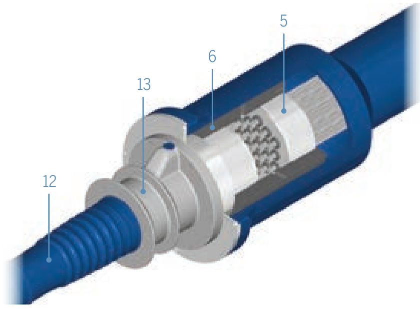
CONA CMI EIT



CONA CMI SP Anchorage

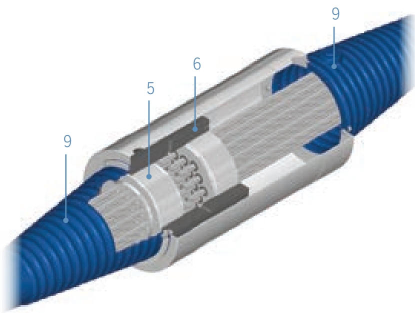


CONA CMI Coupler H



CONA CMI EIT Coupler H

CONA CMI Coupler K



CONA CMI Movable Coupler H

1 – Anchor head
2 – Bearing trumplate
3 – Square plate
4 – Coupler head type K
5 – Coupler head type H
6 – Coupler sleeve type H
7 – Trumpet type A
8 – Trumpet type A SP
9 – Trumpet type K
10 – Steel ring
11 – Isolation disk
12 – Trumpet type E
13 – Bearing trumplate type E
14 – BBR VT Plastic Duct
* – Shown

Minimum radii of curvature - CONA CMI BT/SP

CONA CMI minimum radii of curvature

In Tables 13 and 14, the minimum radii of curvature (R_{min}), eccentricity (e) and inner duct diameter (d_i) are given for various degrees of filling (f), assuming a prestressing force of the tendon of 0.85 $F_{p0.1}$ and allowable contact pressures of 140 kN/m or 200 kN/m.

Loop tendon minimum radii of curvature

In Table 15, the minimum radii of curvature (R_{min}), outer duct diameter (d_o) and duct thickness (t) are given with corresponding eccentricities (e) and degrees of filling (f). Nevertheless other duct sizes can be used, taking due consideration of the minimum wall thickness given in the far right column of the table. Different duct sizes lead to different eccentricities and minimum radii of curvature.

Table 13: CONA CMI minimum radii of curvature and eccentricity for strands **06-140 1,860** and $p_{R,max}$ = 140 and 200 kN/m

Degree of filling	f ≈ 0.35				f ≈ 0.40				f ≈ 0.45			
n 06 Number of strands (A_p = 140 mm²)	d_i	R_{min} 140 kN/m	R_{min} 200 kN/m	e	d_i	R_{min} 140 kN/m	R_{min} 200 kN/m	e	d_i	R_{min} 140 kN/m	R_{min} 200 kN/m	e
	mm	m		mm	mm	m		mm	mm	m		mm
01 06	23*	2.0	2.0	4	20	2.1	2.0	3	20	2.1	2.0	3
02 06	35	2.4	2.0	7	35	2.4	2.0	6	35	2.4	2.0	6
03 06	40	3.2	2.2	6	35	3.6	2.6	2	35	3.6	2.6	2
04 06	45	3.8	2.6	7	40	4.3	3.0	3	40	4.3	3.0	3
05 06	50*	4.3	3.0	8	45	4.7	3.3	4	45	4.7	3.3	4
06 06	55	4.6	3.2	9	50*	5.1	3.6	6	50*	5.1	3.6	6
07 06	60*	5.0	3.5	10	55	5.4	3.8	7	55	5.4	3.8	7
08 06	65	5.2	3.7	11	60*	5.7	4.0	8	55	6.2	4.3	4
09 06	70	5.5	3.8	13	65	5.9	4.1	10	60	6.4	4.5	6
12 06	80	6.4	4.5	15	75*	6.8	4.8	12	70	7.3	5.1	8
13 06	80	6.9	4.8	15	75*	7.4	5.2	10	70	7.9	5.5	6
15 06	85*	7.5	5.3	14	80	8.0	5.6	10	75*	8.5	6.0	7
16 06	90	7.6	5.3	16	85*	8.0	5.6	12	80	8.5	6.0	9
19 06	100*	8.1	5.7	19	90	9.0	6.3	11	85*	9.5	6.7	8
22 06	105	8.9	6.2	19	100*	9.4	6.6	15	95	9.9	6.9	11
24 06	110	9.3	6.5	20	105	9.7	6.8	16	100*	10.2	7.1	12
25 06	115*	9.2	6.5	22	105	10.1	7.1	15	100	10.6	7.4	11
27 06	115*	10.0	7.0	20	110	10.4	7.3	16	105	10.9	7.7	13
31 06	125	10.6	7.4	22	120	11.0	7.7	19	110	12.0	8.4	12
37 06	135	11.7	8.2	23	130*	12.1	8.5	19	120	13.1	9.2	13
42 06	145	12.3	8.6	25	135	13.2	9.3	20	130*	13.7	9.6	16
43 06	150	12.2	8.5	28	140	13.1	9.1	20	130*	14.1	9.9	15
48 06	155	13.2	9.2	30	145	14.1	9.9	21	140	14.6	10.2	17
55 06	165	14.2	9.9	29	155	15.1	10.6	22	145	16.1	11.3	18
61 06	175	14.8	10.4	32	165	15.7	11.0	23	155	16.7	11.7	18
69 06	185	15.9	11.1	34	175	16.8	11.7	25	165	17.8	12.5	19
73 06	195	15.9	11.1	36	180	17.3	12.1	26	170	18.3	12.8	20

Where BBR VT Plastic Ducts are used in tables 13 and 14 (denoted with an *), please refer to the relevant European Technical Assessment or contact your nearest BBR representative.

Table 14: CONA CMI minimum radii of curvature and eccentricity for strands **06-150 1,860** and $p_{R,max}$ = 140 and 200 kN/m

Degree of filling	f ≈ 0.35				f ≈ 0.40				f ≈ 0.45			
n 06 Number of strands (A_p = 150 mm²)	d_i	R_{min} 140 kN/m	R_{min} 200 kN/m	e	d_i	R_{min} 140 kN/m	R_{min} 200 kN/m	e	d_i	R_{min} 140 kN/m	R_{min} 200 kN/m	e
	mm	m		mm	mm	m		mm	mm	m		mm
01 06	23*	2.0	2.0	4	23*	2.0	2.0	4	20	2.3	2.0	2
02 06	35	2.7	2.0	6	35	2.7	2.0	6	35	2.7	2.0	6
03 06	40	3.5	2.5	6	40	3.5	2.5	6	35	4.0	2.8	1
04 06	45	4.2	2.9	6	45	4.2	2.9	6	40	4.7	3.3	2
05 06	50*	4.7	3.3	8	50*	4.7	3.3	8	45	5.2	3.6	3
06 06	55	5.1	3.6	8	55	5.1	3.6	8	50*	5.6	3.9	5
07 06	60*	5.5	3.8	9	60*	5.5	3.8	9	55	6.0	4.2	6
08 06	65	5.8	4.0	11	60*	6.3	4.4	6	60*	6.3	4.4	7
09 06	70	6.0	4.2	12	65	6.5	4.4	9	60*	7.0	4.9	4
12 06	80	7.0	4.9	14	75*	7.5	5.3	11	70	8.0	5.6	7
13 06	85*	7.2	5.0	16	80	7.6	5.3	13	75*	8.1	5.7	9
15 06	90	7.8	5.5	16	85*	8.3	5.8	13	80	8.8	6.2	9
16 06	95	7.9	5.5	18	85*	8.8	6.2	11	85*	8.8	6.2	10
19 06	100*	8.9	6.2	17	95	9.4	6.6	14	90	9.9	6.9	10
22 06	110	9.4	6.6	21	100*	10.3	7.2	13	95	10.9	7.6	10
24 06	115*	9.8	6.9	21	105	10.7	7.5	15	100*	11.3	7.9	11
25 06	115*	10.2	7.1	20	110	10.7	7.5	17	105	11.2	7.8	14
27 06	120	10.6	7.4	21	115*	11.0	7.7	18	105	12.1	8.4	11
31 06	130*	11.2	7.8	24	120	12.1	8.5	17	115*	12.6	8.8	14
37 06	140	12.4	8.7	25	130*	13.3	9.3	19	125	13.9	9.7	15
42 06	150	13.1	9.2	26	140	14.1	9.8	21	135	14.6	10.2	17
43 06	155	13.0	9.1	28	145	13.9	9.7	22	135	14.9	10.5	16
48 06	160	14.1	9.8	29	150	15.0	10.5	24	145	15.5	10.9	21
55 06	175	14.7	10.3	31	160	16.1	1.3	26	150	17.2	12.0	21
61 06	180	15.9	11.1	33	170	16.8	11.8	27	160	17.9	12.5	22
69 06	195	16.6	11.6	35	180	18.0	12.6	29	170	19.0	13.3	23
73 06	200	17.1	12.0	37	185	18.5	13.0	30	175	19.6	13.7	23

Table 15: Minimum radii of curvature and eccentricity for loop tendons with $p_{R,max}$ = 800 kN/m

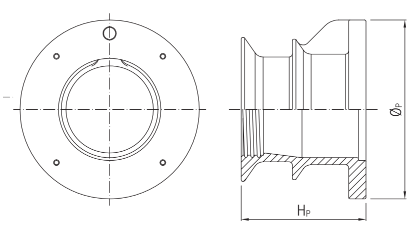
n 06 Number of strands	06-140 1,860					06-150 1,860					Min. wall thickness
	d_o	t	R_{min}	e	f	d_o	t	R_{min}	e	f	t_{min}
	mm	mm	m	mm	-	mm	mm	m	mm	-	mm
04 06	60.3	2.9	0.5	13	0.24	60.3	2.9	0.6	12	0.26	1.5
07 06	76.1	2.9	0.7	17	0.25	76.1	2.9	0.8	19	0.27	1.5
09 06	82.5	3.2	0.9	19	0.28	88.5	3.2	0.9	23	0.26	1.5
12 06	95.0	3.6	1.0	21	0.28	95.0	3.6	1.21	22	0.30	1.5
13 06	101.6	3.6	1.0	23	0.26	101.6	3.6	1.1	25	0.28	1.5
15 06	108.0	3.6	1.1	26	0.26	114.3	3.6	1.1	26	0.25	2.0
19 06	121.0	4.0	1.3	28	0.27	121.0	4.0	1.3	29	0.28	2.0
22 06	133.0	4.0	1.3	31	0.25	133.0	4.0	1.4	33	0.27	2.0
24 06	139.7	4.0	1.4	32	0.25	139.7	4.0	1.5	35	0.26	2.0
25 06	139.7	4.0	1.4	33	0.26	139.7	4.0	1.5	35	0.28	2.0
27 06	139.7	4.0	1.5	35	0.28	152.4	4.5	1.5	39	0.25	3.0
31 06	152.4	4.5	1.6	37	0.27	159.0	4.5	1.7	40	0.26	3.0

Dimensions and detailing - CONA CME BT/SP

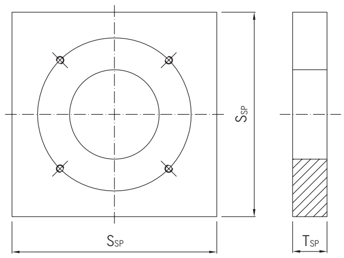
Table 16: CONA CME component dimensions

Number of Strands				01	02	03	04	05	06	07	08	09	12	13
Bearing Trumplate	Diameter	$Ø_P$	mm	–	130	130	130	170	170	170	195	225	225	240
	Height	H_P	mm	–	120	120	120	128	128	128	133	150	150	160
Square Plate	Side length	S_{SP}	mm	80	140	145	155	185	190	205	225	255	265	285
	Height	T_{SP}	mm	20	20	20	25	30	35	35	35	35	35	40
Anchor Head	Nominal diameter	$Ø_A$	mm	50	90	100	100	130	130	130	150	160	160	180
	Height head A1-A4	H_A	mm	50	50	50	50	50	55	55	60	60	65	72
	Height head A5-A8		mm	65	65	65	65	65	65	65	65	65	70	72
Coupler head type K	Diameter	$Ø_K$	mm	–	185	185	185	205	205	205	240	240	240	290
	Height	H_K	mm	–	85	85	85	85	85	85	90	90	90	90
Coupler head type H	Nominal diameter	$Ø_{AH}$	mm	50	90	95	100	130	130	130	150	160	160	180
	Height head H1	H_{AH}	mm	50	50	50	55	55	60	65	65	70	80	80
	Height head H2		mm	65	65	65	65	65	65	65	65	70	80	80
Coupler sleeve type H	Diameter	$Ø_H$	mm	69	111	121	130	160	164	167	189	200	210	230
	Length sleeve	L_H	mm	180	180	180	180	180	190	200	200	210	230	230
Assemblies	BT anchorage	$L_{A,BT}$	mm	–	296	296	296	432	432	432	721	738	623	819
	SP anchorage	$L_{A,SP}$	mm	–	441	441	446	431	436	436	690	774	774	834
	Coupler K	L_{FK}	mm	–	503	503	503	535	535	535	668	668	668	783
	Coupler H	L_{FH}	mm	–	400	400	400	475	485	495	920	930	770	930

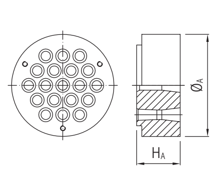
1) Square plate dimensions may be optimised depending on the strength of concrete at transfer. Please contact your nearest BBR representative or refer to the CONA CME ETA document.



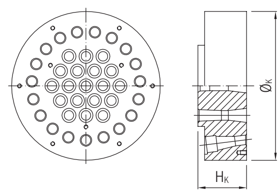
Bearing trumplate



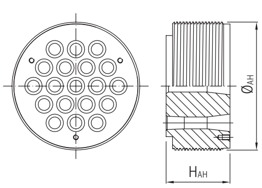
Square plate



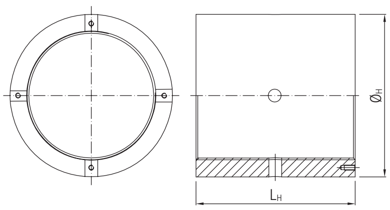
Anchor head



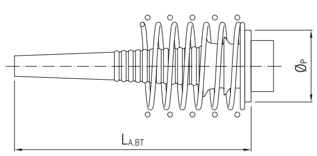
Coupler head type K



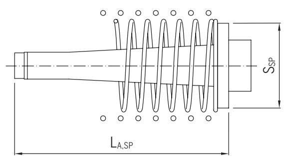
Coupler head type H



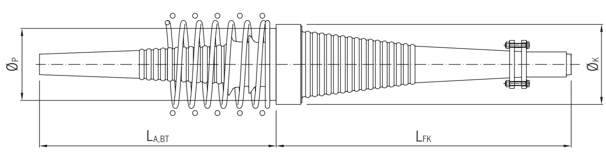
Coupler sleeve type H



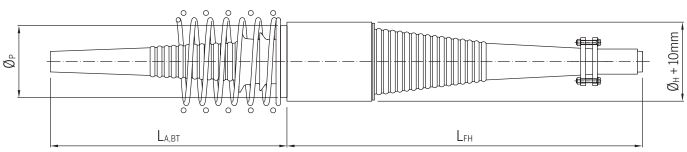
CME BT Anchorage assembly



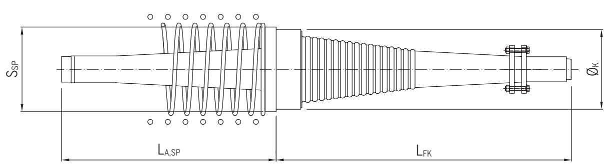
CME SP Anchorage assembly



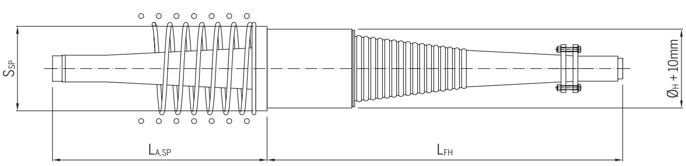
CME BT Coupler K assembly



CME BT Coupler H assembly

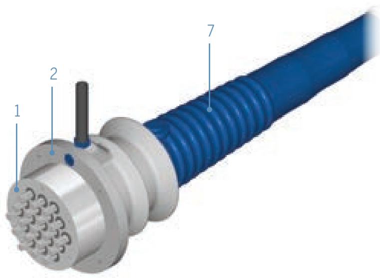


CME SP Coupler K assembly

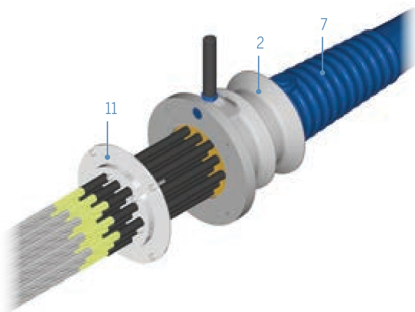


CME SP Coupler H assembly

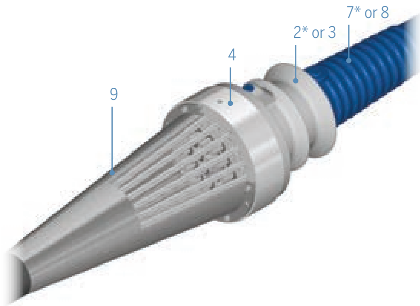
15	16	19	22	24	25	27	31	37	42	43	48	55	61	69	73	91
280	280	280	310	325	360	360	360	400	425	485	485	485	520			
195	195	195	206	227	250	250	250	275	290	340	340	340	350			
320	330	340	370	390	405	415	440	480	510	520	550	595	620			
45	45	50	55	55	60	65	60	70	70	75	80	90	90			
200	200	200	225	240	255	255	255	285	300	320	325	335	365			
75	80	85	95	100	100	105	110	–	–	–	–	–	–			
75	80	85	95	100	100	105	110	120	130	130	140	150	155			
290	290	290	310	340	390	390	390	–	–	–	–	–	–			
90	95	95	105	120	125	125	130	–	–	–	–	–	–			
200	200	200	225	240	255	255	255	285	300	320	325	335	365		on request	
80	85	95	100	100	100	105	115	–	–	–	–	–	–			
80	85	95	100	100	100	105	115	125	135	135	145	160	160			
256	256	266	293	309	324	327	335	370	392	410	422	440	472			
240	250	270	270	280	280	300	320	340	360	360	380	410	410			
854	854	739	886	1,063	1,086	1,086	971	1,295	1,310	1,538	1,538	1,418	1,594			
939	939	944	1,072	1,251	1,210	1,215	1,210	1,340	1,385	1,581	1,586	1,596	1,772			
783	788	788	823	937	1,079	1,079	1,084	–	–	–	–	–	–			
940	950	970	1,040	1,320	1,320	1,340	1,200	on request								



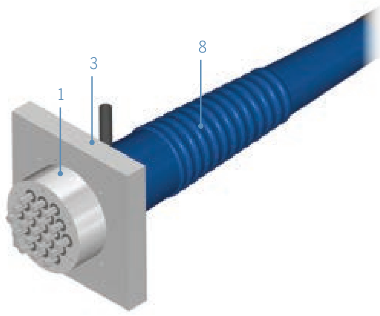
CONA CME BT Anchorage



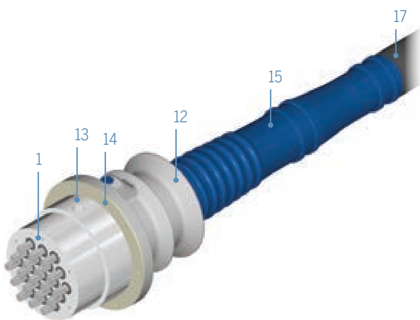
CONA CME BT with monostrands



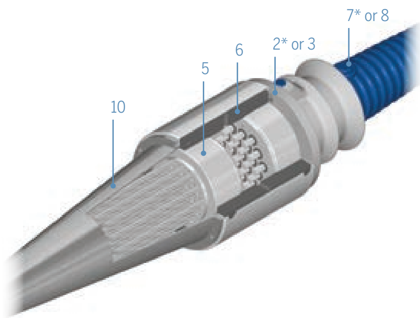
CONA CME Coupler K



CONA CME SP Anchorage



CONA CME EIT **



CONA CME Coupler H

CONA CME Exchangeable

1 – Anchor head
2 – Bearing trumplate
3 – Square plate
4 – Coupler head type K
5 – Coupler head type H
6 – Coupler sleeve type H
7 – Trumpet type A
8 – Trumpet type A SP
9 – Trumpet type CME-K
10 – Trumpet type CME-H
11 – Temporary sealing plate
12 – Bearing trumplate type E
13 – Steel ring
14 – Isolation disc
15 – Trumpet type E
16 – Inner trumpet type E
17 – Smooth plastic duct
* – Shown
** – Exchangeable also possible

Minimum radii of curvature - CONA CME BT/SP

Minimum radii of curvature

The minimum radii of curvature (R_{min}), eccentricity (e), outer duct diameter (d_o), and minimum duct wall thickness (t_{min}) given in Table 17 correspond to a prestressing force of the tendon of 0.85 $F_{p0.1}$, a diameter of the strands of 15.3 mm (06-140 1,860) or 15.7 mm (06-150 1,860) and an allowable contact pressure of 350 kN/m. The given duct diameters result in degrees of filling which are in the range of 0.25 to 0.35, suitable for long tendons with minimum radii of curvature. A higher degree of filling of up to f = 0.45, is possible for shorter tendons and bigger radii of curvature. The standard ratio of wall thickness to outside diameter should not be smaller than 1/25 or minimum 3.0 mm for plastic ducts and 1/65 or minimum 1.5 mm for steel ducts.

For minimum radius of curvature tables using a wax filler, please refer to the BBR VT CONA CME European Technical Assessment.

Table 17: CONA CME minimum radii of curvature for strands **06-140** and **06-150** 1,860 and $p_{R,max}$ = 350 kN/m

Type of Duct	Plastic Duct					Plastic Duct ≈ 1.5 · R_{min}					Steel Duct				
n 06	d_o	t_{min}	R_{min}	e	f	d_o	t_{min}	R_{min}	e	f	d_o	t	R_{min}	e	f
Number of strands	mm	mm	m	mm	–	mm	mm	m	mm	–	mm	mm	m	mm	–
01 06	32	3.0	2.0	9	0.28	32	3.0	3.0	8	0.28	33	1.5	2.0	6	0.21
02 06	40	3.0	2.0	12	0.33	40	3.0	3.0	12	0.33	42	1.5	2.0	14	0.25
03 06	50	3.7	2.0	8	0.32	50	3.0	3.0	9	0.30	48	1.5	2.0	10	0.28
04 06	50	3.7	2.0	6	0.42	63	2.4	3.0	15	0.23	48	1.5	2.0	6	0.38
05 06	63	4.3	2.0	11	0.32	63	2.4	3.0	13	0.28	60	1.5	2.0	12	0.29
06 06	63	4.3	2.0	9	0.39	75	4.5	3.0	16	0.26	60	1.5	2.0	10	0.35
07 06	75	5.6	2.0	12	0.33	75	4.5	3.0	14	0.31	64	1.5	2.0	10	0.36
08 06	75	5.6	2.2	10	0.38	75	4.5	3.3	12	0.35	68	1.5	2.0	11	0.36
09 06	75	5.6	2.2	8	0.42	75	4.5	3.3	10	0.39	73	1.5	2.2	12	0.35
12 06	90	5.4	2.5	14	0.37	90	4.3	3.8	15	0.35	83	1.5	2.5	15	0.36
13 06	90	4.3	2.5	14	0.37	90	4.3	3.8	14	0.37	89	2.0	2.5	15	0.34
15 06	110	5.3	2.7	21	0.29	110	4.2	4.1	24	0.28	89	2.0	2.7	13	0.40
16 06	110	5.3	2.7	19	0.31	110	4.2	4.1	21	0.30	102	2.0	2.7	21	0.32
19 06	110	5.3	3.0	17	0.37	110	4.2	4.5	19	0.35	102	2.0	3.0	17	0.38
22 06	125	6.0	3.2	23	0.33	125	4.8	4.8	24	0.32	114.3	2.0	3.2	21	0.35
24 06	125	6.0	3.3	21	0.36	125	4.8	5.0	22	0.34	114.3	2.0	3.3	19	0.38
25 06	125	6.0	3.3	19	0.37	125	4.8	5.0	20	0.36	121	2.0	3.3	21	0.35
27 06	125	6.0	3.5	17	0.40	125	4.8	5.3	18	0.39	127	2.5	3.5	23	0.35
31 06	140	6.7	3.7	22	0.37	140	5.4	5.6	22	0.35	127	2.5	3.7	19	0.40
37 06	140	6.7	4.0	16	0.44	140	5.4	6.0	18	0.42	141	2.5	4.0	22	0.38
42 06	160	7.7	4.5	24	0.38	160	6.2	6.8	26	0.37	168	3.0	4.5	36	0.31
43 06	160	7.7	4.5	23	0.39	160	6.2	6.8	25	0.38	168	3.0	4.5	35	0.31
48 06	180	8.6	4.5	31	0.35	180	6.9	6.8	33	0.33	168	3.0	4.5	31	0.35
55 06	180	8.6	5.2	25	0.40	180	6.9	7.8	27	0.38	168	3.0	5.2	25	0.40
61 06	200	9.6	5.5	34	0.36	200	7.7	8.3	36	0.34	168	3.0	5.5	21	0.44
69 06	225	12.8	5.6	45	0.33	225	10.3	8.4	53	0.32	193	3.0	5.6	29	0.38
73 06	225	12.8	5.7	39	0.35	225	10.3	8.6	48	0.33	193	3.0	5.9	22	0.40


Table 18: CONA CME with monostrand minimum radii of curvature for strands **06-140** and **06-150** 1,860

Type of Duct	Plastic Duct					Steel Duct				
n 06 Number of strands	d_o	t	R_{min}	e	f	d_o	t	R_{min}	e	f
	mm	mm	m	mm	–	mm	mm	m	mm	–
01 06	32	2.4	2.0	4	0.49	34	1.5	2.0	6	0.38
02 06	50	3.7	2.0	9	0.40	48	1.5	2.0	8	0.36
03 06	63	4.7	2.0	12	0.38	48	1.5	2.0	5	0.53
04 06	75	5.6	2.0	14	0.35	57	1.5	2.0	8	0.50
05 06	75	5.6	2.0	13	0.44	60	1.5	2.0	7	0.56
06 06	75	5.6	2.0	10	0.53	76	1.5	2.0	13	0.41
07 06	90	5.4	2.0	16	0.40	76	1.5	2.0	12	0.47
08 06	90	5.4	2.0	15	0.46	76	1.5	2.0	11	0.54
09 06	90	5.4	2.5	12	0.52	83	1.5	2.5	12	0.51
12 06	110	5.3	2.5	19	0.44	95	1.5	2.5	14	0.51
13 06	110	5.3	2.5	19	0.47	95	1.5	2.5	15	0.55
15 06	125	5.3	2.5	24	0.41	114	2.0	2.5	21	0.45
16 06	125	5.3	2.5	21	0.44	114	2.0	2.5	20	0.48
19 06	125	5.3	2.5	18	0.52	114	2.0	2.5	13	0.57
22 06	140	5.4	2.5	23	0.48	127	2.0	2.5	18	0.52
24 06	140	5.4	2.5	20	0.52	140	2.0	2.5	24	0.47
25 06	140	5.4	2.5	18	0.54	140	2.5	2.5	24	0.50
27 06	140	5.4	2.5	15	0.58	152	2.5	2.5	24	0.45
31 06	160	6.2	2.5	23	0.51	159	2.5	2.5	26	0.47
37 06	180	6.9	2.5	29	0.48	168	2.5	2.5	27	0.50
42 06	180	6.9	2.5	24	0.55	178	3.0	2.5	27	0.51
43 06	180	6.9	2.5	23	0.56	178	3.0	2.5	26	0.52
48 06	200	7.7	2.5	29	0.51	194	3.0	2.5	31	0.49
55 06	225	8.6	2.5	38	0.46	219	3.0	2.5	41	0.44
61 06	225	8.6	2.5	33	0.51	219	3.0	2.5	36	0.49
69 06	250	9.6	2.5	40	0.47	244	3.0	2.5	46	0.44
73 06	250	11.9	2.5	36	0.52	244	3.0	2.5	45	0.47

Spacing & reinforcement requirement - CONA CMI/CME BT

Table 19: CONA CMI/CME BT anchor zone spacing and local reinforcement requirement for strands **06-150** 1,860

CONA CMI/CME BT n06			02 06					03 06					04 06					05 06				
Cube strength	$f_{cm,0}$	MPa	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43
Cylinder strength	$f_{cm,0}$	MPa	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35
Outer diameter HELIX		mm	160	160	160	160	155	160	160	160	160	155	180	160	160	160	155	200	195	195	195	195
Bar diameter		mm	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Pitch		mm	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	50	50	60	50
Number of pitches			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	5	5	5	5
Distance	E	mm	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	18	18	18	18	18
Number of STIRRUPS			3	3	3	3	3	4	3	4	4	3	3	3	4	4	3	4	4	4	3	4
Bar diameter		mm	8	8	8	8	8	8	10	8	8	10	12	12	10	10	12	12	12	12	12	12
Spacing		mm	55	55	55	55	55	45	45	45	45	55	60	55	45	45	55	55	50	50	65	50
Distance	F	mm	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	33	33	33	33	33
Min. outer dimensions	A = B	mm	190	190	190	190	190	190	190	190	190	190	220	200	190	190	190	250	230	230	230	230
Centre spacing	$a_c = b_c$	mm	210	210	210	210	205	210	210	210	210	205	235	215	210	210	205	265	250	250	250	250
Edge distance (+ c)	$a_e' = b_e'$	mm	95	95	95	95	95	95	95	95	95	95	110	100	95	95	95	125	115	115	115	115

CONA CMI/CME BT n06			13 06					15 06					16 06					19 06				
Cube strength	$f_{cm,0}$	MPa	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43
Cylinder strength	$f_{cm,0}$	MPa	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35
Outer diameter HELIX		mm	375	330	300	280	270	375	330	315	305	305	375	330	320	310	305	420	360	360	330	325
Bar diameter		mm	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Pitch		mm	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Number of pitches			8	8	8	7	6	9	9	8	7	7	9	9	9	8	7	10	10	9	9	8
Distance	E	mm	23	23	23	23	23	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Number of STIRRUPS			7	6	6	6	7	7	6	5	6	5	7	6	5	6	6	7	7	7	7	7
Bar diameter		mm	12	14	14	14	14	14	16	16	16	16	14	16	16	16	16	16	16	16	16	16
Spacing		mm	55	60	55	60	45	60	65	65	55	60	60	65	65	60	60	65	65	65	65	60
Distance	F	mm	40	40	40	40	40	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Min. outer dimensions	A = B	mm	410	370	340	320	310	440	400	360	350	350	450	410	370	360	350	490	450	410	390	370
Centre spacing	$a_c = b_c$	mm	425	390	355	340	325	455	415	380	365	365	470	430	390	375	365	510	465	425	410	390
Edge distance (+ c)	$a_e' = b_e'$	mm	205	185	170	160	155	220	200	180	175	175	225	205	185	180	175	245	225	205	195	185

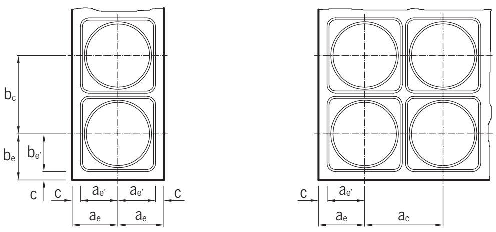
CONA CMI/CME BT n06			37 06					42 06					43 06					48 06				
Cube strength	$f_{cm,0}$	MPa	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43
Cylinder strength	$f_{cm,0}$	MPa	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35
Outer diameter HELIX		mm	–	580	580	580	580	–	630	630	630	630	–	670	670	670	670	–	710	710	710	710
Bar diameter		mm	–	16	16	16	16	–	16	16	16	16	–	16	16	16	16	–	16	16	16	16
Pitch		mm	–	50	50	50	50	–	50	50	50	50	–	50	50	50	50	–	50	50	50	50
Number of pitches			–	11	11	11	11	–	12	12	12	12	–	12	12	12	12	–	13	13	13	13
Distance	E	mm	–	40	40	40	40	–	45	45	45	45	–	45	45	45	45	–	45	45	45	45
Number of STIRRUPS			–	9	9	9	9	–	10	10	10	10	–	10	10	10	10	–	11	11	11	11
Bar diameter		mm	–	20	20	20	20	–	20	20	20	20	–	20	20	20	20	–	20	20	20	20
Spacing		mm	–	70	70	70	70	–	70	70	70	70	–	70	70	70	70	–	70	70	70	70
Distance	F	mm	–	50	50	50	50	–	55	55	55	55	–	55	55	55	55	–	55	55	55	55
Min. outer dimensions	A = B	mm	–	660	660	660	660	–	720	720	720	720	–	740	740	740	740	–	790	790	790	790
Centre spacing	$a_c = b_c$	mm	–	680	680	680	680	–	735	735	735	735	–	755	755	755	755	–	805	805	805	805
Edge distance (+ c)	$a_e' = b_e'$	mm	–	330	330	330	330	–	360	360	360	360	–	370	370	370	370	–	395	395	395	395

1) If smaller centre spacing and edge distances are required, refer to page 42 for guidance on space reduction. 2) All helix and stirrup reinforcement shall be ribbed reinforcing steel of grade 500 MPa. Grade 460 MPa steel may also be used if one additional stirrup of equivalent size is placed within the same length of the anchorage zone. The indicated stirrup spacings will have to be reduced accordingly. 3) Bar diameter of 14 mm can be replaced by 16 mm. 4) Prestressing strand with nominal diameter of 15.3 mm, cross sectional area of 140 mm^2 or with characteristic tensile strength below 1,860 MPa may also be used.

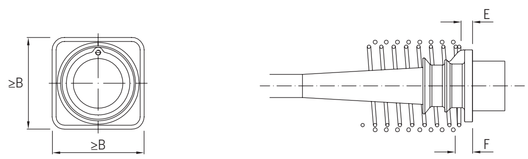
06 06					07 06					08 06					09 06					12 06				
23	28	34	38	43	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43
19	23	28	31	35	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35
200	200	195	195	195	230	200	200	200	200	270	230	225	220	220	280	260	255	250	250	330	280	275	260	250
10	10	10	10	10	12	12	12	12	12	14	12	12	12	12	14	12	12	12	12	14	14	14	14	14
45	50	50	60	50	45	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
6	5	5	5	5	6	6	5	5	5	6	6	5	6	6	6	6	6	6	6	7	7	7	7	6
18	18	18	18	18	18	18	18	18	18	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
5	4	5	3	4	5	4	4	4	4	4	6	5	4	5	5	5	5	4	5	7	6	5	5	6
12	12	12	12	12	14	14	12	14	14	12	12	12	14	14	12	14	12	14	14	12	14	16	16	14
50	55	45	65	50	55	60	55	55	55	70	45	50	55	50	60	55	55	65	55	60	55	70	70	50
33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	35	35	35	35	35	35	35	35	35	35
270	250	230	230	230	290	270	240	240	240	310	290	260	260	260	330	300	290	290	290	390	350	320	310	290
290	265	250	250	250	310	285	260	255	255	330	305	280	275	275	350	320	310	310	310	405	370	340	325	310
135	125	115	115	115	145	135	120	120	120	155	145	130	130	130	165	150	145	145	145	195	175	160	155	145

22 06					24 06					25 06					27 06					31 06				
23	28	34	38	43	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43	23	28	34	38	43
19	23	28	31	35	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35	19	23	28	31	35
475	420	390	360	340	475	430	410	360	360	520	430	420	390	380	520	475	440	420	390	560	520	475	430	430
14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
10	10	9	9	8	11	11	10	10	9	11	11	10	10	9	11	11	10	10	9	11	11	12	10	9
31	31	31	31	31	32	32	32	32	32	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
6	7	8	7	8	7	7	7	7	8	7	6	7	7	7	8	7	7	8	8	9	8	8	8	8
20	20	20	20	16	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
80	75	65	65	50	80	80	70	65	55	80	90	70	60	60	80	80	75	60	60	80	75	70	65	60
46	46	46	46	46	47	47	47	47	47	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
530	480	440	420	400	560	510	460	440	420	570	520	470	450	430	590	540	490	470	440	630	580	530	500	480
550	500	460	440	420	575	525	480	460	435	590	535	485	465	450	610	555	505	485	460	650	595	545	520	495
265	240	220	210	200	280	255	230	220	210	285	260	235	225	215	295	270	245	235	220	315	290	265	250	240

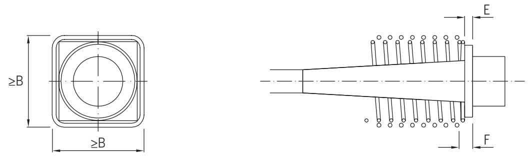
55 06					61 06				
23	28	34	38	43	23	28	34	38	43
19	23	28	31	35	19	23	28	31	35
–	780	780	780	780	–	850	850	850	850
–	20	20	20	20	–	20	20	20	20
–	60	60	60	60	–	60	60	60	60
–	13	13	13	13	–	14	14	14	14
–	50	50	50	50	–	55	55	55	55
–	11	11	11	11	–	12	12	12	12
–	20	20	20	20	–	20	20	20	20
–	75	75	75	75	–	75	75	75	75
–	55	55	55	55	–	60	60	60	60
–	860	860	860	860	–	920	920	920	920
–	875	875	875	875	–	940	940	940	940
–	430	430	430	430	–	460	460	460	460



$a_e = a_{e'} + c$
$b_e = b_{e'} + c$



CMI/CME BT Anchorage assembly



CMI/CME SP Anchorage assembly

Spacing & reinforcement requirement – CONA CMI/CME SP

Table 20: CONA CMI/CME SP anchor zone spacing and local reinforcement requirement for strands **06-150** 1,860

CONA CMI/CME SP n06			01 06						02 06						03 06						04 06					
Cube strength	$f_{cm,0}$	MPa	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46
Cylinder strength	$f_{cm,0}$	MPa	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38
Outer diameter HELIX		mm	100	100	75	75	75	75	130	130	100	100	100	100	165	160	130	130	120	120	195	190	165	150	145	140
Bar diameter		mm	10	10	10	8	8	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Pitch		mm	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Number of pitches			3	3	2.5	2.5	2.5	2.5	4	4	3.5	3.5	3.5	3.5	4.5	4.5	4	4	4	4	5	5	4.5	4.5	4.5	4.5
Distance	E	mm	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	25	25	25	25	25	25
Number of STIRRUPS			2	2	2	2	2	2	2	2	3	3	2	2	3	3	6	5	5	5	4	3	5	4	4	4
Bar diameter		mm	6	6	6	6	6	6	6	6	6	6	6	6	10	10	8	8	8	8	10	10	10	10	10	10
Spacing		mm	80	75	70	65	60	60	110	110	60	55	90	90	80	80	30	35	35	35	65	90	45	55	50	50
Distance	F	mm	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	45	45	45	45	45	45
Min. outer dimensions	A = B	mm	100	95	85	80	75	75	150	145	130	125	115	115	185	180	165	155	150	145	215	210	190	180	170	165
Centre spacing	$a_c = b_c$	mm	120	115	105	100	95	95	170	165	150	145	135	135	205	200	185	175	170	165	235	230	210	200	190	185
Edge distance (+ c)	$a_e' = b_e'$	mm	50	50	45	40	40	40	75	75	65	65	60	60	95	90	85	80	75	75	110	105	95	90	85	85

CONA CMI/CME SP n06			12 06						13 06						15 06						16 06					
Cube strength	$f_{cm,0}$	MPa	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46
Cylinder strength	$f_{cm,0}$	MPa	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38
Outer diameter HELIX		mm	325	320	290	280	270	260	340	330	305	290	280	270	370	350	325	300	290	280	390	370	340	330	310	310
Bar diameter		mm	12	12	12	14	14	14	12	12	12	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Pitch		mm	45	45	50	50	50	50	45	45	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Number of pitches			8	8	7	6.5	6.5	5.5	8.5	8	7	7	6.5	6	8.5	8	7.5	7.5	7	6.5	8.5	8.5	8	7.5	7.5	6.5
Distance	E	mm	35	35	35	35	35	35	40	40	40	40	40	40	45	45	45	45	45	45	45	45	45	45	45	45
Number of STIRRUPS			7	6	7	6	6	6	7	6	6	6	6	6	7	6	6	6	6	6	7	6	7	6	6	7
Bar diameter		mm	14	14	16	16	16	16	14	14	16	16	16	16	14	14	16	16	16	16	14	14	16	16	16	16
Spacing		mm	55	65	55	60	60	55	65	70	65	65	60	60	70	80	70	70	65	65	70	80	60	70	65	55
Distance	F	mm	55	55	55	55	55	55	60	60	60	60	60	60	65	65	65	65	65	65	65	65	65	65	65	65
Min. outer dimensions	A = B	mm	385	375	345	325	310	300	405	390	360	340	320	310	435	420	390	370	350	340	450	435	400	380	360	350
Centre spacing	$a_c = b_c$	mm	410	395	365	345	330	320	425	410	380	360	340	330	455	440	410	390	370	360	470	455	420	400	380	370
Edge distance (+ c)	$a_e' = b_e'$	mm	195	190	175	165	155	150	205	195	180	170	160	155	220	210	195	185	175	170	225	220	200	190	180	175

CONA CMI/CME SP n06			31 06						37 06						42 06						43 06					
Cube strength	$f_{cm,0}$	MPa	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46
Cylinder strength	$f_{cm,0}$	MPa	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38
Outer diameter HELIX		mm	560	540	480	430	430	430	620	620	620	620	620	620	660	660	660	660	660	660	670	670	670	670	670	670
Bar diameter		mm	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Pitch		mm	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Number of pitches			11	11	10	10	9	8.5	12	12	12	12	12	12	13	13	13	13	13	13	14	14	14	14	14	14
Distance	E	mm	60	60	60	60	60	60	70	70	70	70	70	70	75	75	75	75	75	75	75	75	75	75	75	75
Number of STIRRUPS			8	7	10	9	8	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Bar diameter		mm	20	20	20	20	20	20	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Spacing		mm	80	95	60	65	70	65	60	60	60	60	60	60	65	65	65	65	65	65	70	70	70	70	70	70
Distance	F	mm	80	80	80	80	80	80	90	90	90	90	90	90	95	95	95	95	95	95	95	95	95	95	95	95
Min. outer dimensions	A = B	mm	630	605	560	535	515	500	695	695	695	695	695	695	745	745	745	745	745	745	755	755	755	755	755	755
Centre spacing	$a_c = b_c$	mm	650	625	580	555	535	520	715	715	715	715	715	715	765	765	765	765	765	765	775	775	775	775	775	775
Edge distance (+ c)	$a_e' = b_e'$	mm	315	305	280	270	260	250	350	350	350	350	350	350	375	375	375	375	375	375	380	380	380	380	380	380

1) If smaller centre spacing and edge distances are required, refer to page 42 for guidance on space reduction. 2) All helix and stirrup reinforcement shall be ribbed reinforcing steel of grade 500 MPa. Grade 460 MPa steel may also be used if one additional stirrup of equivalent size is placed within the same length of the anchorage zone. The indicated stirrup spacings will have to be reduced accordingly. 3) Bar diameter of 14 mm can be replaced by 16 mm. 4) Prestressing strand with nominal diameter of 15.3 mm, cross sectional area of 140 mm^2 or with characteristic tensile strength below 1,860 MPa may also be used.

05 06						06 06						07 06						08 06						09 06					
26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46
21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38
215	200	185	170	160	160	250	230	210	180	175	175	260	255	220	210	195	190	280	270	230	215	205	200	295	280	240	225	215	215
10	10	10	10	10	10	10	10	12	12	12	12	10	10	12	12	12	12	10	10	12	12	12	12	10	10	10	10	12	12
45	45	50	50	50	50	45	45	50	50	50	50	45	45	50	50	50	50	45	45	50	50	50	50	45	45	50	50	50	50
6	5.5	5	4.5	4.5	4.5	6	6	5	5	4.5	4.5	6.5	6.5	5.5	5.5	5	5	7	6.5	5.5	5.5	5.5	5	7	7	6	6	6	5
30	30	30	30	30	30	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
2	2	5	4	4	3	3	2	4	3	3	3	5	4	5	5	5	4	5	4	3	3	3	3	5	4	4	4	3	4
12	12	10	10	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	16	16	16	16	12	12	16	16	16	16
175	170	50	60	60	80	115	185	70	95	90	90	70	85	60	60	55	70	70	90	120	110	105	100	75	95	90	85	110	75
50	50	50	50	50	50	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
245	235	220	205	195	190	270	260	240	225	210	205	295	280	260	250	235	225	315	300	280	265	250	240	330	320	295	280	265	255
265	255	240	225	215	210	290	280	260	245	230	225	315	300	280	270	255	245	335	320	300	285	270	260	355	340	315	300	285	275
125	120	110	105	100	95	135	130	120	115	105	105	150	140	130	125	120	115	160	150	140	135	125	120	170	160	150	140	135	130

19 06						22 06						24 06						25 06						27 06					
26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46
21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38
435	410	380	350	340	340	460	430	400	360	350	350	480	460	410	370	360	360	500	480	420	380	370	370	520	500	450	400	390	380
16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
8.5	8.5	8.5	8	7.5	6.5	9.5	9.5	9	8.5	8	7	10	9.5	9	9	8.5	7.5	10	10	9.5	9.5	8.5	8	10.5	10.5	9.5	9.5	9	8.5
50	50	50	45	45	45	55	55	55	55	55	55	55	55	55	55	55	55	60	60	60	60	60	60	60	60	60	60	60	60
7	6	9	8	7	7	7	6	9	8	8	7	7	6	10	9	8	7	7	6	9	9	8	7	6	5	7	6	6	6
14	14	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	20	20	20	20	20	20
70	85	50	55	60	55	80	95	55	60	55	65	85	100	50	55	60	70	90	100	60	55	60	70	100	130	80	90	85	85
70	70	70	70	70	70	75	75	75	75	75	75	75	75	75	75	75	75	80	80	80	80	80	80	80	80	80	80	80	80
490	470	435	415	395	385	530	510	470	445	425	415	550	530	495	465	445	435	565	545	500	475	450	440	585	565	520	495	470	460
510	490	455	435	415	405	550	530	490	465	445	435	575	550	515	485	465	455	585	565	520	495	470	460	605	585	540	515	490	480
245	235	220	210	200	195	265	255	235	225	215	210	280	265	250	235	225	220	285	275	250	240	225	220	295	285	260	250	235	230

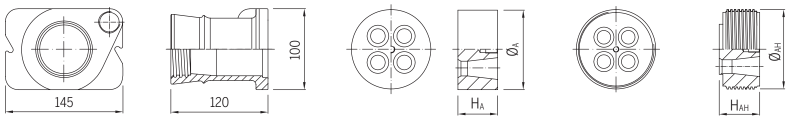
48 06						55 06						61 06						69 06						73 06					
26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46	26	28	34	38	43	46
21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38	21	23	28	31	35	38
720	720	720	720	720	720	760	760	760	760	760	760	860						920						960					
20	20	20	20	20	20	20	20	20	20	20	20	25						25						25					
60	60	60	60	60	60	60	60	60	60	60	60	60						60						60					
15	15	15	15	15	15	16	16	16	16	16	16	17						19						20					
80	80	80	80	80	80	90	90	90	90	90	90	90						100						110					
10	10	10	10	10	10	12	12	12	12	12	12	13						13						13					
16	16	16	16	16	16	16	16	16	16	16	16	16						20						20					
80	80	80	80	80	80	75	75	75	75	75	75	70						85						85					
100	100	100	100	100	100	110	110	110	110	110	110	110						120						130					
810	810	810	810	810	810	885	885	885	885	885	885	940						1,020						1,060					
830	830	830	830	830	830	905	905	905	905	905	905	960						1,040						1,055					
405	405	405	405	405	405	445	445	445	445	445	445	470						510						520					

* See general arrangements on page 53 for guidance.

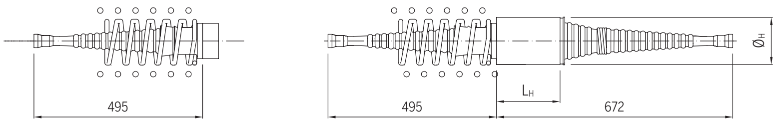
Dimensions and detailing – CONA CMF S1

Table 21: CONA CMF S1 component dimensions

Number of Strands				02	03	04
Anchor Head	Diameter	$Ø_A$	mm	90	100	100
	Height head A1-A4	H_A	mm	50	50	50
	Height head A5-A8		mm	65	65	65
Coupler head type H	Nominal diameter	$Ø_{AH}$	mm	90	100	100
	Height head H1	H_{AH}	mm	50	50	55
	Height head H2		mm	65	65	65
Coupler sleeve type H	Diameter	$Ø_H$	mm	114	121	130
	Length	L_H	mm	180	180	180



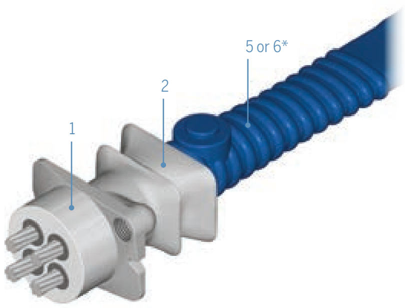
Bearing trumplate Anchor head Coupler head type H



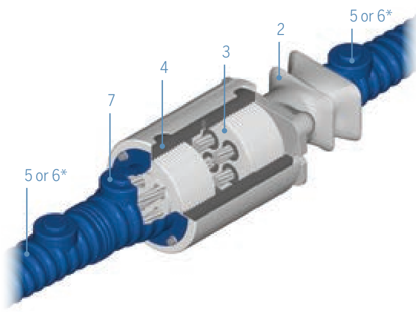
CMF S1 anchorage assembly CMF S1 coupler H assembly

All dimensions in millimeters (mm)

Anchorage and coupler configurations



CONA CMF S1 BT Anchorage



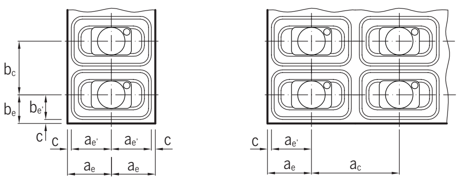
CONA CMF S1 Coupler H

1 – Anchor head
2 – Bearing trumplate
3 – Coupler head type H
4 – Coupler sleeve type H
5 – Trumpet type A
6 – Trumpet type F
7 – Trumpet type FH
* – Shown

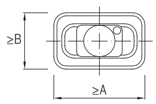
Table 22: CONA CMF S1 anchor zone spacing and local reinforcement requirement for strands ***05*-100** 1,860 and **06-150** 1,860

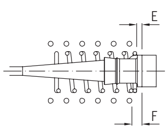
CONA CMF S1			02 *05*		03 *05*		04 *05*		02 06		03 06		04 06	
Cube strength	$f_{cm,0}$	MPa	21	25	21	25	21	25	21	25	21	25	21	25
Cylinder strength	$f_{cm,0}$	MPa	17	20	17	20	17	20	17	20	17	20	17	20
Outer diameter HELIX		mm	– / –	– / –	– / –	– / –	– / –	– / –	– / –	– / –	– / –	240 / 110	– / –	240 / 130
Bar diameter		mm	–	–	–	–	–	–	–	–	–	10	–	10
Pitch		mm	–	–	–	–	–	–	–	–	–	45	–	45
Number of pitches			–	–	–	–	–	–	–	–	–	6	–	7
Distance	E	mm	–	–	–	–	–	–	–	–	–	15	–	15
Number of STIRRUPS			4	4	4	4	7	7	4	4	–	6	–	7
Bar diameter		mm	8	8	10	10	10	10	10	10	–	10	–	10
Spacing		mm	50	50	50	50	50	50	50	50	–	50	–	50
Distance	F	mm	35	35	35	35	35	35	35	35	–	35	–	35
Min. outer dimensions	A / B	mm	160 / 120	160 / 120	190 / 130	160 / 120	320 / 155	320 / 155	190 / 130	160 / 120	– / –	290 / 155	– / –	290 / 180
Centre spacing	a_c / b_c	mm	180 / 140	180 / 140	210 / 150	180 / 140	340 / 175	340 / 175	210 / 150	180 / 140	– / –	310 / 175	– / –	310 / 200
Edge distance (+ c)	a_e' / b_e'	mm	80 / 60	80 / 60	95 / 65	80 / 60	160 / 80	160 / 80	95 / 65	80 / 60	– / –	145 / 80	– / –	145 / 90

1) If smaller centre spacing and edge distances are required, refer to page 42 for guidance on space reduction. 2) All helix and stirrup reinforcement shall be ribbed reinforcing steel of grade 500 MPa. Grade 460 MPa steel may also be used if one additional stirrup of equivalent size is added and spacing reduced to 40mm. 3) Stirrups may be replaced by rectangular helixes of identical bar diameter and external dimensions, and number of turns equal to number of stirrups plus one. 4) Prestressing strand with nominal diameter of 12.9/15.3 mm, cross sectional area of 100/140 mm^2 or with characteristic tensile strength below 1,860 MPa may also be used.



$a_e = a_{e'} + c$
$b_e = b_{e'} + c$

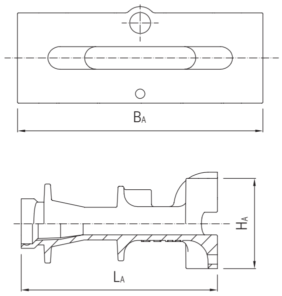




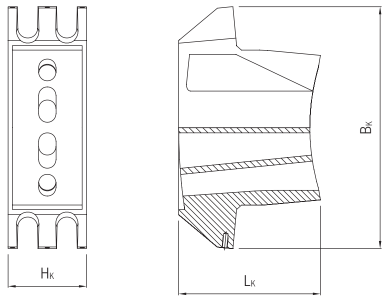
Dimensions and detailing - CONA CMF S2

Table 23: CONA CMF S2 component dimensions

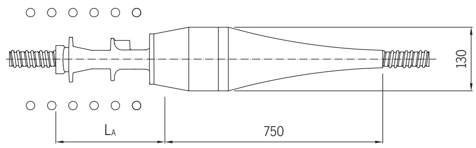
Number of Strands			03 *05*/02 06	04 *05*/03 06	05 *05*/04 06	06 *05*/05 06
Bearing trumplate	Width	B_A	165	190	220	265
	Height	H_A	70	70	80	90
	Length	L_A	109	164	174	243
Coupler K	Width	B_K	288	288	322	359
	Height	H_K	105	105	105	120
	Length	L_K	155	155	155	180



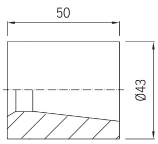
Bearing trumplate



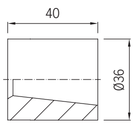
Coupler K



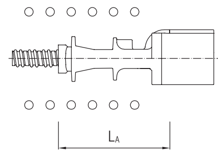
CMF S2 Coupler K assembly



Anchor head 06



Anchor head 05

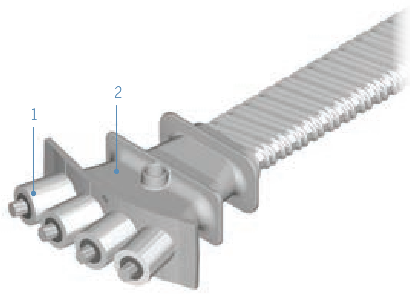


CMF S2 Anchorage A assembly

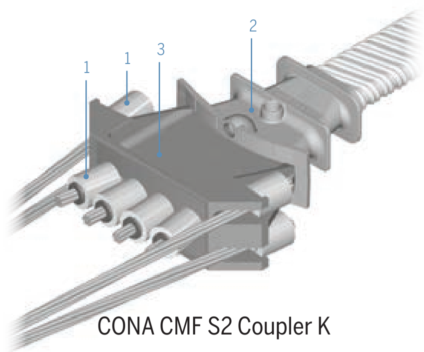
All dimensions in millimeters (mm)

Anchorage and coupler configurations

1 – Barrel
2 – Bearing trumplate
3 – Coupler head type K



CONA CMF S2 Anchorage

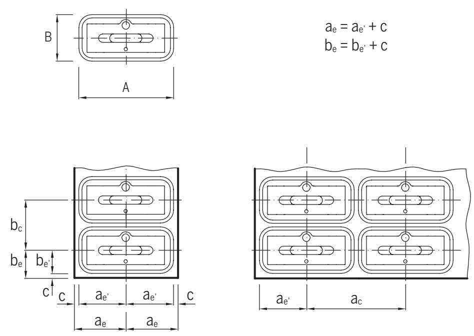


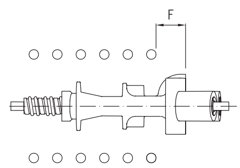
CONA CMF S2 Coupler K

Table 24: CONA CMF S2 anchor zone spacing and local reinforcement requirement for strands ***05*-100** 1,860 and **06-150** 1,860

CONA CMF S2			03 *05*/02 06	04 *05*/03 06	05 *05*/04 06	06 *05*/05 06
Cube strength	$f_{cm,0}$	MPa	26	26	26	26
Cylinder strength	$f_{cm,0}$	MPa	21	21	21	21
Number of STIRRUPS			3	4	6	6
Bar diameter		mm	10	12	12	12
Spacing		mm	40	40	35	40
Distance from anchor plate	F	mm	40	40	40	40
Min. outer dimensions	A / B	mm	200 / 90	230 / 100	270 / 100	310 / 120
Centre spacing	a_c / b_c	mm	220 / 150	300 / 165	370 / 175	450 / 200
Edge distance (+c)	a_e' / b_e'	mm	100 / 65	140 / 75	175 / 80	215 / 90

1) If smaller centre spacing and edge distances are required, refer to page 42 for guidance on space reduction. 2) All helix and stirrup reinforcement shall be ribbed reinforcing steel of grade 500 MPa. Grade 460 MPa steel may also be used if one additional stirrup of equivalent size is added and spacing reduced to 40mm. 3) Stirrups may be replaced by rectangular helixes of identical bar diameter and external dimensions, and number of turns equal to number of stirrups plus one. 4) Prestressing strand with nominal diameter of 12.9/15.3 mm, cross sectional area of 100/140 mm² or with characteristic tensile strength below 1,860 MPa may also be used.






Minimum radius of curvature – CONA CMF S1 and S2

Minimum radii of curvature
The minimum radii of curvature of the tendon (R_{min}) is governed by the limiting radii of curvature for *05* and 06 strands. The minimum radii of curvature, eccentricity (e) and inner duct dimensions (d_i) for the corrugated steel ducts and BBR VT Plastic Duct are given in Tables 25, 26 and 27.

Table 25: CONA CMF S1 minimum radii of curvature, round steel duct dimensions and eccentricity

	Round steel duct											
Degree of filling	f ≈ 0.25				f ≈ 0.30				f ≈ 0.35			
Number of Strands	d_i	R_{min}		e	d_i	R_{min}		e	d_i	R_{min}		e
		140 kN/m	200 kN/m			140 kN/m	200 kN/m			140 kN/m	200 kN/m	
	mm	m		mm	mm	m		mm	mm	m		mm
02 *05*	30	1.7	1.7	6	30	1.8	1.7	6	30	1.8	1.7	6
03 *05*	40	1.8	1.7	8	35	2.1	1.7	6	35	2.6	1.8	6
04 *05*	45	2.6	1.8	10	40	2.6	1.8	8	40	2.6	1.8	8
02 06	40	2.0	2.0	7	35	2.6	2.0	6	35	2.6	2.0	6
03 06	50	2.7	2.0	10	45	3.2	2.2	8	40	3.9	2.7	6
04 06	55	3.9	2.7	13	50	3.9	2.7	9	45	3.9	2.7	6

Table 26: CONA CMF S1 and S2 minimum radii of curvature, flat steel duct dimensions and eccentricity

	Degree of filling	Flat steel duct			
System compatibility	Number of Strands	d_i major	d_i minor	R_{min} 140-200 kN/m	e
		mm	mm	m	mm
CONA CMF S1 & S2	02 *05*	40	20	1.7	3.6
CONA CMF S1 & S2	03 *05*	55	20		3.6
CONA CMF S1 & S2	04 *05*	70	20		3.6
CONA CMF S2	05 *05*	70	20		3.6
CONA CMF S2	06 *05*	90	20		3.6
CONA CMF S1 & S2	02 06	40	20	2.0	2.2
CONA CMF S1 & S2	03 06	55	20		2.2
CONA CMF S1 & S2	04 06	70	20		2.2
CONA CMF S2	05 06	90	20		2.2

Table 27: CONA CMF S1 and S2 minimum radii of curvature, BBR VT Plastic Duct dimensions and eccentricity

Corrugated Plastic Duct								
System compatibility	d_i major	d_i minor	R_{min} major			e		
			n*05*-100	n06-140	n06-150	n*05*-100	n06-140	n06-150
	mm	mm	m			mm		
CONA CMF S1 & S2	40	20	1.7	2.0	2.0	3.6	2.4	2.2
CONA CMF S1 & S2	70	21				4.1	2.9	2.7
CONA CMF S1 & S2	70	21				4.1	2.9	2.7
CONA CMF S2	90	21				4.1	2.9	2.7

The indicated minimum radii of curvature values assume that the temperature of the concrete next to the plastic duct does not exceed 37 °C at the time of tendon stressing operations. For values at higher temperatures, please refer to the relevant European Technical Assessment or contact your nearest BBR representative.

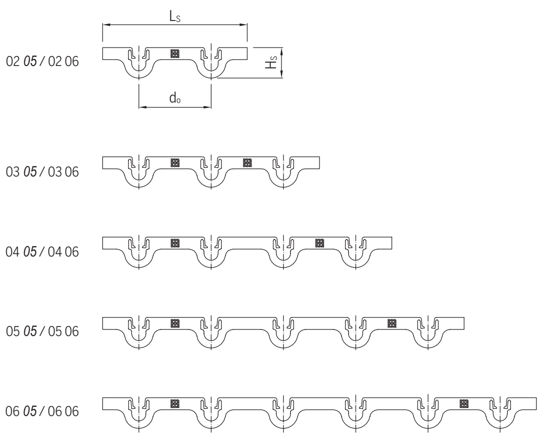
Dimensions and detailing – CONA CMO

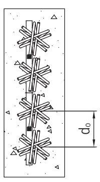
Table 28: CONA CMO component dimensions

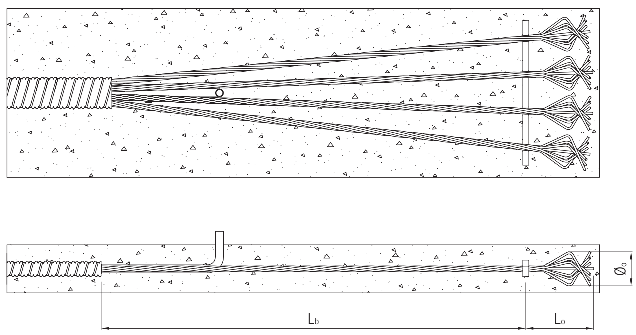
Number of strands			*05*					06				
			02 *05*	03 *05*	04 *05*	05 *05*	06 *05*	02 06	03 06	04 06	05 06	06 06
Bond length	L_b	mm	1,150	1,150	1,150	1,150	1,200	1,400	1,400	1,400	1,400	1,600
Center spacing	d_0	mm	75					90				
Bulb-end length	L_0	mm	130 - 150					130 - 150				
Bulb-end diameter	$Ø_0$	mm	75 ± 10					90 ± 10				
Length spacer	L_S	mm	150	225	300	375	450	180	270	360	450	540
Height spacer	H_S	mm	38					38				

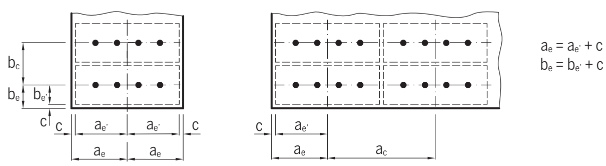
Table 29: CONA CMO anchor zone spacing and local reinforcement requirement for strands ***05*-100** 1,860 and **06-150** 1,860

CONA CMO			02 *05*	03 *05*	04 *05*	05 *05*	06 *05*	02 06	03 06	04 06	05 06	06 06
Cube strength	$f_{cm,0}$	MPa	26	26	26	26	26	26	26	26	26	26
Cylinder strength	$f_{cm,0}$	MPa	21	21	21	21	21	21	21	21	21	21
Outer diameter HELIX		mm	–	–	–	–	–	–	–	–	–	–
Bar diameter		mm	–	–	–	–	–	–	–	–	–	–
Pitch		mm	–	–	–	–	–	–	–	–	–	–
Number of pitches			–	–	–	–	–	–	–	–	–	–
Distance	E	mm	–	–	–	–	–	–	–	–	–	–
Number of STIRRUPS			–	–	–	–	–	–	–	–	–	–
Bar diameter		mm	–	–	–	–	–	–	–	–	–	–
Spacing		mm	–	–	–	–	–	–	–	–	–	–
Distance	F	mm	–	–	–	–	–	–	–	–	–	–
Min. outer dimensions	B	mm	–	–	–	–	–	–	–	–	–	–
Center spacing	a_c / b_c	mm	180/150	270/150	350/150	440/150	530/150	220/180	320/180	420/180	520/180	630/180
Edge distance (+ c)	a_e' / b_e'	mm	90/75	135/75	175/75	220/75	265/75	110/90	160/90	210/90	260/90	315/90

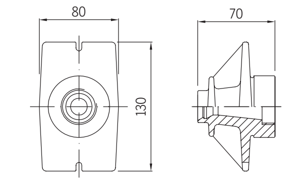




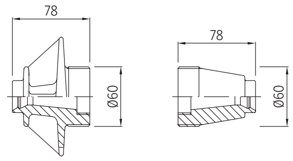




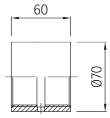
Dimensions and detailing - CONA CMM Single S1



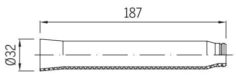
CMM Single S1 Anchorage



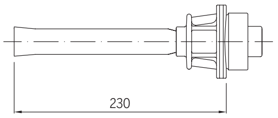
CMM Single S1 Coupler type H



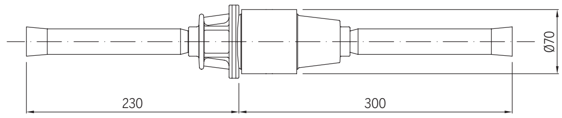
CMM Single S1
Coupler sleeve type H



Transition pipe



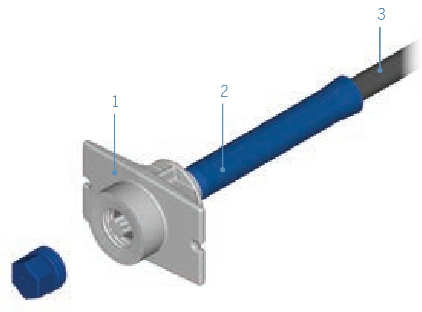
CMM Single S1 Anchorage assembly



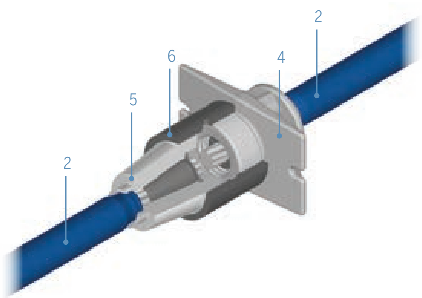
CMM Single S1 Coupler H assembly

All dimensions in millimeters (mm)

Anchorage and coupler configurations



CONA CMM Single S1 Anchorage



CONA CMM Single S1 Coupler H

1 – Load transfer element
2 – Transition pipe
3 – Monostrand
4 – Coupler type H load transfer element
5 – Coupler head type H
6 – Coupler sleeve type H

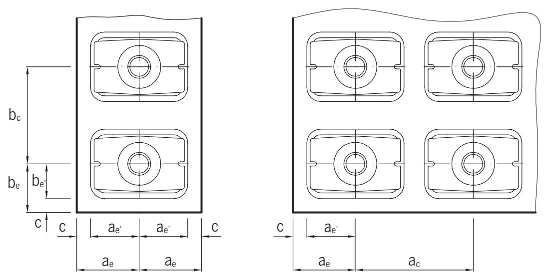
Minimum radius of curvature

The minimum radius of curvature of a CONA CMM Single S1 (R_{min}) is 2.5 m. Smaller radii are possible for special applications.

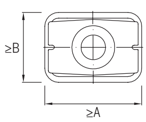
Table 30: CONA CMM Single S1 anchor zone spacing and local reinforcement requirement for strands **06-150** 1,860 and **06C-165** 1,820

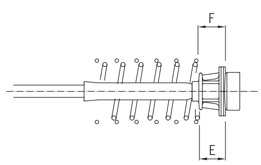
CONA CMM Single S1			01 06
Cube strength	$f_{cm,0}$	MPa	24
Cylinder strength	$f_{cm,0}$	MPa	20
Outer diameter HELIX		mm	-
Bar diameter		mm	-
Pitch		mm	-
Number of pitches			-
Distance	E	mm	-
Number of STIRRUPS			2
Bar diameter		mm	8
Spacing		mm	50
Distance	F	mm	55
Min. outer dimensions	A / B	mm	140 / 100
Center spacing	a_c / b_c	mm	180 / 140
Edge distance (+ c)	a_e' / b_e'	mm	70 / 50

1) If smaller centre spacing and edge distances are required, refer to page 42 for guidance on space reduction. 2) All helix and stirrup reinforcement shall be ribbed reinforcing steel of grade 500 MPa. Grade 460 MPa steel may also be used if one additional stirrup of equivalent size is added and spacing reduced to 40mm. 3) Stirrups may be replaced by rectangular helixes of identical bar diameter and external dimensions, and number of turns equal to number of stirrups plus one. 4) Prestressing strand with nominal diameter of 12.9/15.3 mm, cross sectional area of 100/140 mm² or with characteristic tensile strength below 1,860 MPa may also be used.

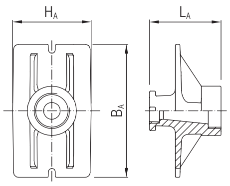


$a_e = a_{e'} + c$
$b_e = b_{e'} + c$

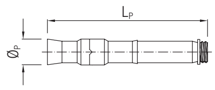




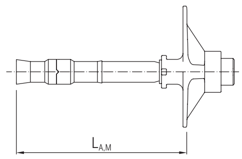
Dimensions and detailing - CONA CMM Single S2



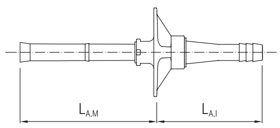
CMM Single S2 Anchorage



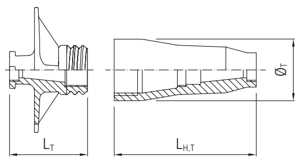
Transition pipe



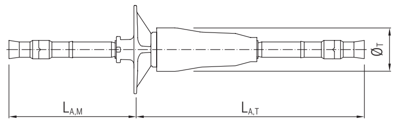
CMM Single S2
Anchorage assembly



CMM Single S2
Intermediate anchorage assembly



CMM Single S2 Coupler T



CMM Single S2 Coupler T assembly

All dimensions in millimeters (mm)

Table 31: CONA CMM Single S2 component dimensions

		Anchorages			Transition / Protection pipe		Coupler T			Assemblies		
		H_A	L_A	B_A	L_P	$Ø_P$	L_T	$Ø_T$	$L_{H,T}$	$L_{A,M}$	$L_{A,I}$	$L_{A,T}$
01 *05*	mm	63	56	120	150	26	67	55	138	168	–	292
01 *05* Intermediate	mm				114	24	–	–	–		135	–
01 06	mm	80	73	135	186	30	84	63	153	208	–	356
01 06 Intermediate	mm				124	28	–	–	–		158	–

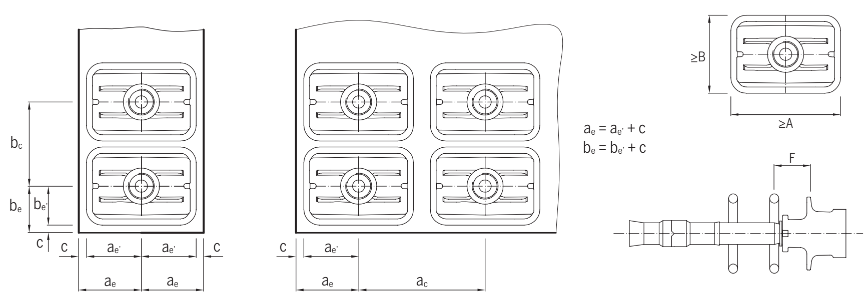
Minimum radius of curvature

The minimum radius of curvature is 2.0 m for bonded applications. For monostrand applications the minimum radius of curvature is 2.5 m.

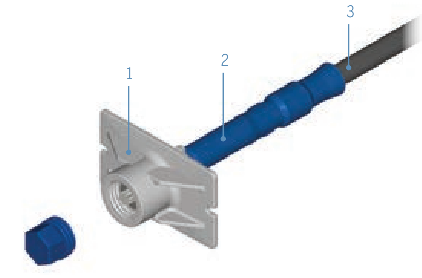
Table 32: CONA CMM Single S2 anchor zone spacing and local reinforcement requirement for strands ***05*-100** 1,860 and **06-150** 1,860.

CONA CMM Single S2			**01 *05***		**01 06**	
Cube strength	$f_{cm,0}$	MPa	22	23	22	23
Cylinder strength	$f_{cm,0}$	MPa	18	19	18	19
Number of STIRRUPS*			2		2	
Bar diameter		mm	8		10	
Spacing		mm	40		45	
Distance	F	mm	40		40	
Min. outer dimensions	A / B	mm	145 / 75		155 / 85	
Center spacing	a_c / b_c	mm	165 / 95	220 / 140	175 / 105	235 / 150
Edge distance (+c)	a_e / b_e	mm	73 / 38	100 / 60	78 / 43	108 / 65

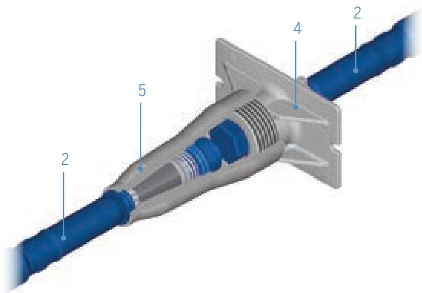
Footnotes to Table 30 are also applicable.



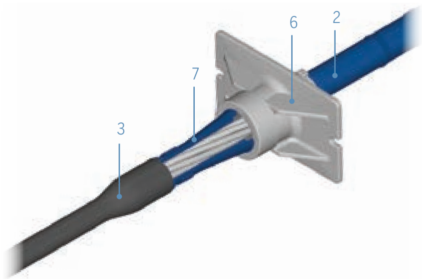
Anchorage and coupler configurations



CONA CMM Single S2 Anchorage



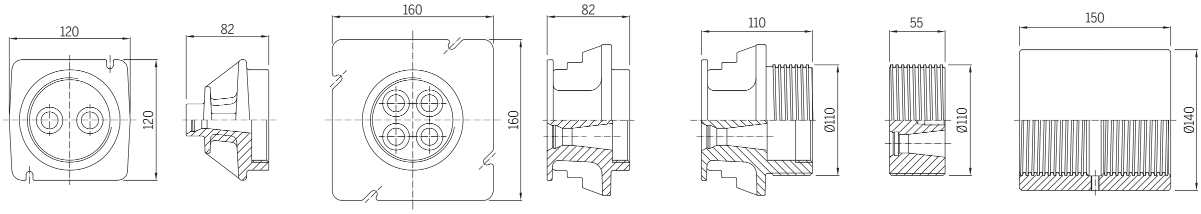
CONA CMM Single S2 Coupler T



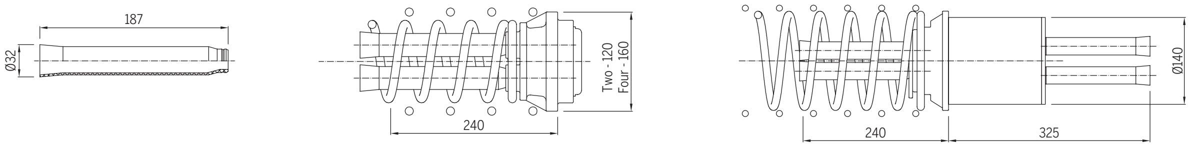
CONA CMM Single S2 Intermediate Anchorage

1 – Load transfer element
2 – Transition pipe
3 – Monostrand
4 – Coupler type T anchorage
5 – Coupler head type T
6 – Intermediate anchorage
7 – Protection pipe

Dimensions and detailing - CONA CMM Two/Four

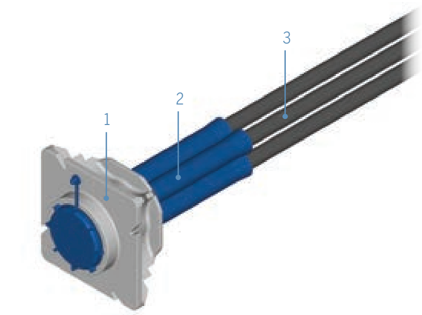


CMM Two Anchorage CMM Four Anchorage CMM Four Coupler type H CMM Four Coupler sleeve type H

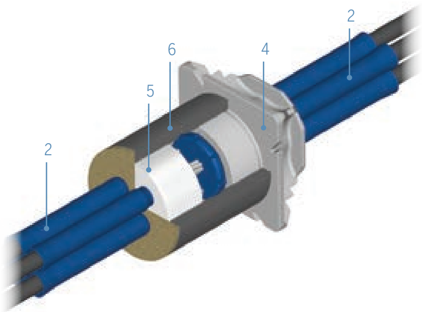


Transition pipe CMM Two/Four Anchorage assembly CMM Four Coupler H assembly All dimensions in millimeters (mm)

Anchorage and coupler configurations



CONA CMM Two/Four Anchorage



CONA CMM Four Coupler H

1 – Load transfer element
2 – Transition pipe
3 – Monostrand
4 – Coupler type H load transfer element
5 – Coupler head type H
6 – Coupler sleeve type H

Minimum radii of curvature

In Table 33, the minimum radii of curvature of the tendon (R_{min}) is shown against the type of tendon. Smaller radii are possible for special applications.

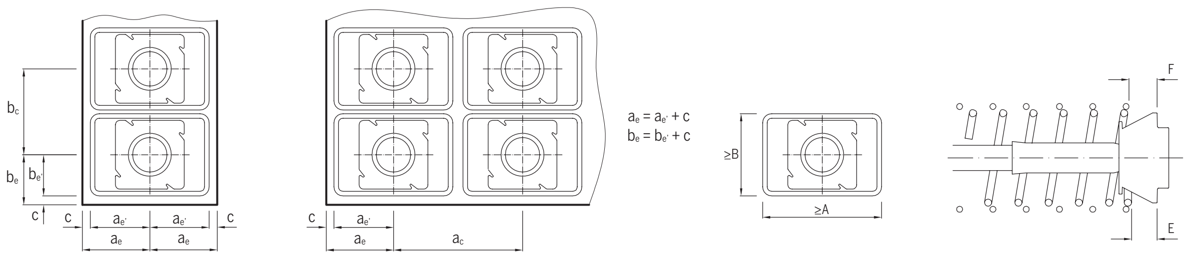
Table 33: CONA CMM Two/Four minimum radii of curvature

Number of strands	R_{min}
n	m
02 06	3.5
04 06	3.5

Table 34: CONA CMM Two/Four anchor zone spacing and local reinforcement requirement for strands **06-150** 1,860 and **06C-165** 1,820

CONA CMM Two/Four			**02 06**	**04 06**
Cube strength	$f_{cm,0}$	MPa	24	24
Cylinder strength	$f_{cm,0}$	MPa	20	20
Outer diameter HELIX		mm	100	160
Bar diameter		mm	10	12
Pitch		mm	40	50
Number of pitches			4	5
Distance	E	mm	50	45
Number of STIRRUPS			4	6
Bar diameter		mm	10	10
Spacing		mm	50	55
Distance	F	mm	25	53
Min. outer dimensions	A / B	mm	180 / 130	260 / 180
Center spacing	a_c / b_c	mm	200 / 150	300 / 220
Edge distance (+ c)	a_e' / b_e'	mm	90 / 65	130 / 90

1) If smaller centre spacing and edge distances are required, refer to page 42 for guidance on space reduction. 2) All helix and stirrup reinforcement shall be ribbed reinforcing steel of grade 500 MPa. Grade 460 MPa steel may also be used if one additional stirrup of equivalent size is added and spacing reduced to 40mm. 3) Stirrups may be replaced by rectangular helixes of identical bar diameter and external dimensions, and number of turns equal to number of stirrups plus one. 4) Prestressing strand with nominal diameter of 15.3 mm, cross sectional area of 140 mm² or with characteristic tensile strength below 1,860 MPa may also be used.

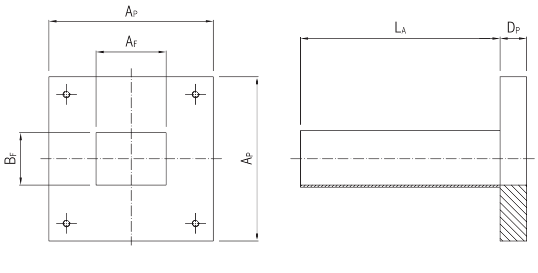


Dimensions and detailing – CONA CMB

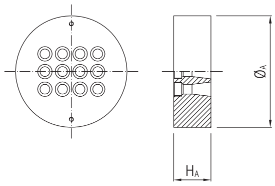
Table 35: CONA CMB component dimensions

Number of strands				01 x 01 06	01 x 02 06	02 x 02 06	03 x 02 06	01 x 04 06	02 x 04 06	03 x 04 06	04 x 04 06
Anchor head	Diameter	$Ø_A$	mm	60	100	110	160	180	180	200	210
	Height	H_A	mm	60	60	60	60	60	60	60	70
Anchor plate and recess tube	Side length	A_P x A_P	mm	80	120	160	200	230	230	270	310
	Thickness	D_P	mm	10	15	20	25	30	30	40	50
	Opening	A_F x B_F	mm	34 x 34	64 x 34	64 x 64	64 x 104	134 x 34	134 x 64	134 x 104	134 x 134
	Min. length	L_A	mm	300	300	300	300	300	300	300	300

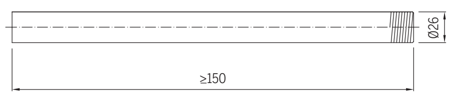
All dimensions in millimeters (mm)



Anchor plate and recess tube

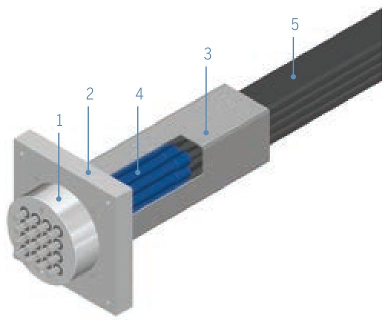


Anchor head



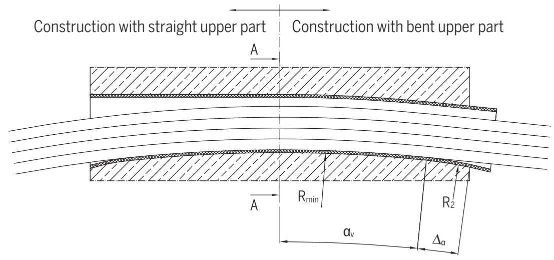
Transition pipe

Anchorage configuration

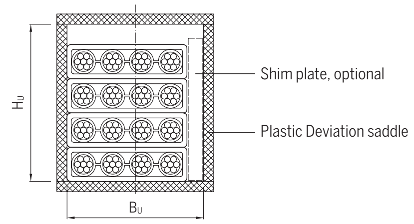


CONA CMB SP Anchorage

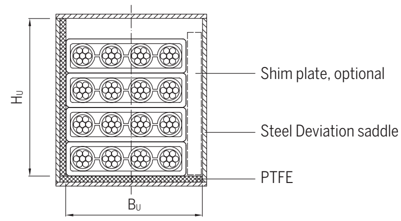
1 – Anchor head
2 – Square plate
3 – Recess tube
4 – Transition pipe
5 – Strand band bundles



Critical Dimensions at Deviator/Saddle
$* = R_2 < R_{min}$



Section A-A
Plastic devation saddle



Section A-A
Steel devation saddle

Minimum radii of curvature

In Table 36, the minimum radii of curvature of the tendon (R_{min}) is given corresponding to a prestressing force of the tendon of 0.85 $F_{p0,1}$, a inner sheathing thickness of 1.75 mm and a radius of curvature around the second, perpendicular axis $R_H \geq 10$ m. Other radii are applicable for special applications or other types of strand subject to consultation and approval with the ETA holder.

Table 36: CONA CMB minimum radii of curvature and saddle dimensions

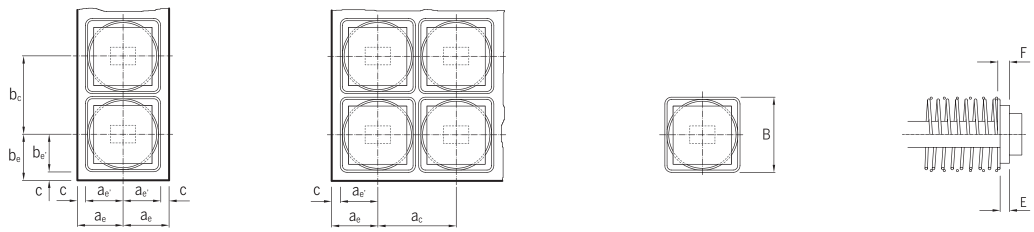
Band configuration	Bands	Number of strands	R_{min}			Min. width	Min. height
			n06-140	n06-150	n06C-165	B_u	H_u
		n06	m			mm	mm
01 x 01 06	1	01 06	2.0	2.0	2.0	35	40
01 x 02 06	1	02 06	2.0	2.0	2.0	70	40
02 x 02 06	2	04 06	2.8	3.0	2.2	70	70
03 x 02 06	3	06 06	4.2	4.5	3.4	70	100
01 x 04 06	1	04 06	2.0	2.0	2.0	110	40
02 x 04 06	2	08 06	2.8	3.0	2.2	110	70
03 x 04 06	3	12 06	4.2	4.5	3.4	110	100
04 x 04 06	4	16 06	5.6	6.0	4.5	110	130

Spacing & reinforcement requirement - CONA CMB

Table 37: CONA CMB SP anchor zone spacing and local reinforcement requirement for strands **06-150** 1,860 and **06C-165** 1,820

CONA CMB SP n06			01 06	02 06 (1 x 2)	04 06 (2 x 2)	06 06 (3 x 2)	04 06 (1 x 4)	08 06 (2 x 4)	12 06 (3 x 4)	16 06 (4 x 4)
Cube strength	$f_{cm,0}$	MPa	35	35	35	35	35	35	35	35
Cylinder strength	$f_{cm,0}$	MPa	29	29	29	29	29	29	29	29
Outer diameter HELIX		mm	-	-	180	210	210	260	320	380
Bar diameter		mm	-	-	10	12	12	14	14	14
Pitch		mm	-	-	40	50	50	50	50	50
Number of pitches			-	-	5	5	6	6	6.5	7
Distance	E	mm	-	-	25	30	30	30	40	50
Number of STIRRUPS			3	5	4	4	4	4	6	6
Bar diameter		mm	12	12	10	12	12	12	12	12
Spacing		mm	40	40	55	70	70	70	65	70
Distance	F	mm	30	35	45	50	50	50	60	70
Min. outer dimensions	A = B	mm	90	140	200	240	230	275	340	400
Center spacing	$a_c = b_c$	mm	115	160	220	260	250	290	370	420
Edge distance (+ c)	$a_e' = b_e'$	mm	50	70	100	120	115	135	180	200

1) If smaller center spacing and edge distances are required, refer to page 42 for guidance on space reduction. 2) All helix and stirrup reinforcement must be ribbed reinforcing steel of grade 500 MPa. Grade 460 MPa steel may also be used if one additional stirrup of equivalent size is placed within the same length of the anchorage zone. The indicated stirrup spacings will have to be reduced accordingly. 3) Bar diameter of 14 mm can be replaced by 16 mm. 4) Prestressing strand with nominal diameter of 15.3 mm, cross-sectional area of 140 mm² or with characteristic tensile strength below 1,860 MPa may also be used.



$a_e = a_{e'} + c$
$b_e = b_{e'} + c$

Notations, units and references

List of Notations		
A	[mm]	minimum horizontal outer dimensions of additional reinforcement
A_{gt}	[%]	minimum elongation at maximum force of prestressing steel
A_c	[mm^2]	minimum concrete area in the local zone
A_p	[mm^2]	nominal cross-sectional area of prestressing steel
a_c	[mm]	minimum horizontal center spacing
a_c	[mm]	reduced minimum horizontal center spacing (15% rule)
a_e	[mm]	minimum horizontal edge distance
$a_{e'}$	[mm]	minimum horizontal edge distance without cover
B	[mm]	minimum vertical outer dimensions of additional reinforcement
b_c	[mm]	minimum vertical center spacing
b_c	[mm]	reduced minimum vertical centre spacing (15% rule)
b_e	[mm]	minimum vertical edge distance
$b_{e'}$	[mm]	minimum vertical edge distance without cover
c	[mm]	concrete cover
d	[mm]	nominal strand diameter
d_i	[mm]	inner diameter of duct, major and minor axis dimensions may also be indicated for flat ducts
d_o	[mm]	outer diameter of duct, major and minor axis dimensions may also be indicated for flat ducts
E	[mm]	distance of helix lowercase from anchor plate
E_p	[MPa]	modulus of elasticity of prestressing steel
e	[mm]	eccentricity of the tendon
F	[mm]	distance of additional reinforcement from the anchor plate
f	[-]	degree of filling
$f_{ck,cube}$	[MPa]	characteristic concrete compressive strength (cubic specimen)
$f_{ck,cylinder}$	[MPa]	characteristic concrete compressive strength (cylindrical specimen)
$f_{cm,cube}$	[MPa]	mean concrete compressive strength (cubic specimen)
$f_{cm,cylinder}$	[MPa]	mean concrete compressive strength (cylindrical specimen)
$f_{cm,0}$	[MPa]	mean concrete compressive strength at the time of full prestressing
f_{pk}	[MPa]	maximum characteristic tensile strength of prestressing steel
F_{pk}	[kN]	characteristic value of maximum force of tendon
$f_{p0.1}$	[kN]	characteristic value of 0.1% proof stress of the tendon
$F_{p0.1}$	[kN]	characteristic value of 0.1% proof force of the tendon
$F_{pm,0}$	[kN]	prestressing force of the tendon
f_{pp}	[MPa]	limit of proportionality of prestressing steel
F_o	[kN]	prestressing force at x = 0 m
f_R	[-]	converting factor from 1,860 MPa strand to 1,770 MPa strand
F_x	[kN]	prestressing force at a distance x along the tendon
G.C.D.	[mm]	center of gravity of the duct
G.C.S.	[mm]	center of gravity of the strands
k	[rad/m]	wobble coefficient
k_{as}	[m^{-1}]	wobble equivalent coefficient (American Standards)
K_f	[-]	stable factor
L_{min}	[mm]	minimum straight length
M	[kg/m]	mass per meter of prestressing steel
n	[-]	number of strands in a tendon
OD_{Helix}	[mm]	outer diameter of helix
$p_{R,max}$	[kN/m]	maximum contact pressure between prestressing strands, duct and concrete
R_b	[m]	minimum radius of curvature to protect the strand from excessive bending stresses
R_{min}	[m]	minimum radius of curvature
t_{min}	[mm]	minimum wall thickness of duct
x	[m]	distance along the tendon from the point where the prestressing force is equal to F_0
α	[rad]	sum of angular displacements over distance x
μ	[rad^{-1}]	friction coefficient

Notations, units and references

List of Units	
kg	kilogram (1 kg = 1,000 gram)
in.	inch (1 in. = 25.4 mm)
m	meter
mm	millimeter
mm^2	square millimeter
Pa	Pascal (1 N/m^2)
MPa	megapascal (1 MPa = 1 N/mm^2)
N	Newton [$kg \cdot m \cdot s^{-2}$] (1 kg ≈ 9.81 N)
kN	kilonewton (1 kN = 1,000 N)
rad	radiant (2π = 360 deg)
s	second

Guidelines	
EAD16 (ETAG 013)	Guideline for European Technical Assessment of Post-Tensioning Kits for Prestressing of Structures
fib Bulletin 75	Corrugated plastic ducts for internal bonded post-tensioning

Standards	
EN 206-1+A1+A2 (06.2005)	Concrete – Part 1: Specification, performance, production and conformity
EN 445 (10.2007)	Grout for prestressing tendons – Test methods
EN 446 (10.2007)	Grout for prestressing tendons – Grouting procedures
EN 447 (10.2007)	Grout for prestressing tendons – Specification for common grout
EN 523 (08.2003)	Steel strip sheaths for prestressing tendons – Terminology, requirements, quality control
EN 1561 (06.1997)	Founding – Grey cast irons
EN 1563+A1+A2 (07.2005)	Founding – Spheroidal graphite cast irons
EN 1992-1-1+AC (01.2008)	Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings
EN 10025-2+AC (06.2005)	Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels
EN 10083-1 (08.2006)	Quenched and tempered steels – Part 1: Technical delivery conditions for special steels
EN 10083-2 (08.2006)	Quenched and tempered steels – Part 2: Technical delivery conditions for unalloyed quality steels
EN 10084 (04.2008)	Case hardening steels – Technical delivery conditions
EN 10204 (10.2004)	Metallic products – Types of inspection documents
EN 10210-1 (04.2006)	Hot finished structural hollow sections of non-alloy and fine grain structural steels – Part 1: technical delivery requirements
EN 10216-1+A1 (03.2004)	Seamless steel tubes for pressure purposes – Technical delivery conditions – Part 1: Non-alloy steel tubes with specified room temperature properties
EN 10217-1+A1 (01.2005)	Welded steel tubes for pressure purposes – Technical delivery conditions – Part 1: Non-alloy steel tubes with specified room temperature properties
EN 10219-1 (04.2006)	Cold formed welded structural hollow sections of non-alloy and fine grain steels – Part 5 1: Technical delivery conditions
EN 10255 (04.2007)	Non-alloy steel tubes suitable for welding and threading – Technical delivery conditions
EN 10270-1 (04.2001)	Steel wire for mechanical springs – Part 1: Patented cold drawn unalloyed steel wire
EN 10277-2 (03.2008)	Bright steel products – Technical delivery conditions – Part 2: Steels for general engineering purposes
EN 10305-5 (01.2010)	Steel tubes for precision applications – Technical delivery conditions – Part 5: Welded and cold sized square and rectangular tubes
EN 12201 (03.2003)	Plastics piping systems for water supply – Polyethylene (PE)
EN ISO 1872-1 (05.1999)	Plastics – Polyethylene (PE) moulding and extrusion materials – Part 1: Designation system and basis for specifications (ISO 2872-1:1993)
EN ISO 1874-1 (09.2000)	Plastics – Polyamide (PA) moulding and extrusion materials – Part 1: Designation (ISO 1874-1:1992)
prEN 10138-3 (08.2009)	Prestressing steels – Part 3: Strands
CWA 14646 (01.2003)	Requirements for the installation of post-tensioning kits for prestressing of structures and qualification of the specialist company and its personnel
DIN 1045-1	German standards – design of reinforced and prestressed concrete structures
SIA 262	Swiss standards – concrete structures
AS/NZS 4672.1:2007	Standards Australia – steel prestressing Materials – part 1: General requirements
ASTM A416	Standard Specification for Steel Strand, Uncoated Seven Wire for Prestressed Concrete

And finally ...

Having reached this page, you can certainly be in no doubt as to our commitment to the finest technology and our enthusiasm for delivering our projects.

Our seven decades of experience has resulted in BBR technology being applied to thousands of structures around the world and, in the process, we have continued to refine and enhance our range. The result is that we can supply simply the best technology available – the BBR VT CONA CMX system.

Technology does not however develop by itself – all through the years, we have been fortunate enough to have attracted some of the best engineers in the business. It is their dedication which has maintained the BBR reputation – and continues to do so today.

Our well-established worldwide network is supported in the development of major structures by our Special ProjectsTeam who will help to specify and procure the systems required. So, local knowledge synchronises with international know-how to realise projects – some large, some smaller, but always technically excellent and fit-for-purpose!

BBR VT International Ltd
Ringstrasse 2
8603 Schwerzenbach (ZH)
Switzerland

Tel +41 44 806 80 60
Fax +41 44 806 80 50

www.bbrnetwork.com
info@bbrnetwork.com

BBR VT International Ltd
Technical Headquarters and Business Development Centre
Switzerland

A Global Network of Experts
www.bbrnetwork.com