BBR
ISO 9001
SQS certified 1996

BBR

Cables for External Prestressing

BBR Cables for External Prestressing

1. Introduction

1.1 General History

The first applications of external prestressing date back to the late twenties, when Karl Dischinger used external tendons for the first prestressed concrete bridges in Germany. Until the late sixties, external prestressing was applied to some bridges in Belgium, France and England. Due to the unadequate corrosion protection of these early applications many of the external tendons corroded. External prestressing gained a poor reputation by these experiences.

External prestressing was revitalized and found a new field of application in the strengthening of prestressed concrete structures starting from the seventies. Many bridges predominantly of the precast segmental type were insufficiently prestressed at the time of their construction. The required strengthening by tendons, is necessarily external to the concrete.

Based on the experience of these repairs, the external prestressing has received a new boost. The technique was thus developed largely in the United States from 1978 on and in France from 1980 on.

Since then, many important bridges all over the world have been constructed using external prestressing. The application of external tendons prooved to be particularly suitable for long bridges in segmental construction with a tight schedule thus demanding a very quick production rate.

1.2. Technical Features of External Prestressing

External prestressing is characterized by the following features:

- The tension elements resp. prestressing tendons are placed on the outside of the physical cross-section (mostly in concrete) of the structure
- The forces exerted by the prestressing tendons are only transferred to the structure at the anchorages and at deviators
- No bond is present between the cable and the structure, unless at anchorages or deviators bond is intentionally created.

As a consequence of above the following conclusions can be drawn:

- The application of external prestressing is indeed not bound to the use with concrete, but it can be combined with any construction material as composite materials, steel, timber, steel and concrete combined and other modern plastic materials. This can considerably widen the scope of the post-tensioning applications.

- As the tendons are outside of the structure, the tendons are more exposed to any environmental influences and the protection against these detrimental influences is therefore of special concern.

- Due to the exposure and accessibility of the tendons, surveillance and maintenance measures are facilitated compared to internal, bonded prestressing.

- Due to the absence of bond, it is also possible to restress, destress and exchange any external prestressing cable, provided that the structural detailing allows for these actions.

1.3 Advantages and Disadvantages

Compared to internal and bonded prestressing the external prestressing has the following distinct advantages:

a) Facilitating of concrete placing due to the absence of tendons in the webs, and ease for placing tendons.

b) Improvement of conditions for tendon installation which can take place independently from the concrete works.

c) Reduction of friction losses, because the unintentional angular changes, known as wobble, are practically eliminated. Furthermore, in case of the use of a polyethylene sheathing the friction coefficient is drastically reduced compared to standard internal and bonded prestressing using corrugated sheat metal ducts.

d) External prestressing tendons can easily and without major cost implication be designed to be replaceable, de- and restressable. Corresponding structural detailing, providing sufficient unobstructed space requirements is to be considered.

e) Generally the webs can be made thinner, resulting in an overall lighter structure.

As an overall result, better concrete quality can be obtained leading to a more durable structure and facilitating execution.

On the other hand the following disadvantages can be associated with external prestressing:

a) The tendons are more exposed to environmental influences (fires, vandalism, aggressive chemicals etc.).

b) The deviators and anchor plates have to be placed very accurately, which might sometimes be delicate.

c) As the tendons are not bonded to the concrete (or only at particular points), the ultimate strength can not be developed in ultimate design resulting in a higher prestressing steel consumption.

d) Usually the statical height of the cross-section can not be fully utilized, therefore requiring a greater depth or additional prestressing.

e) For certain cross-sections and construction procedures the handling of the tensioning devices may be more difficult.

1.4 Typical Applications for External Prestressing

Typical applications where external tendons are feasible, practical and economical, are:

- Repair work and strengthening of all kinds of structures
- Underslung structures
- Precast segmental construction, simple and continuous spans
- Incremental launching procedure, in particular centric prestressing

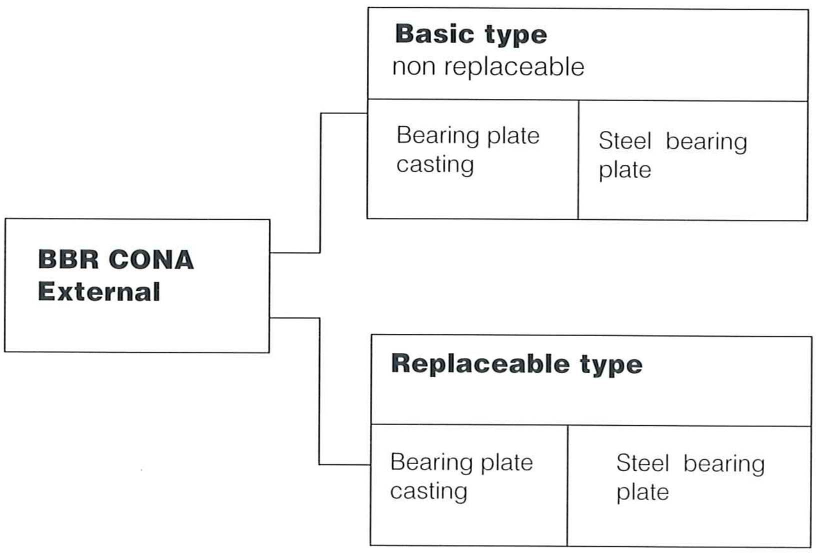
2. BBR Tendon Systems for External Prestressing

BBR Systems Ltd, its affiliated companies and licensees can provide external tendon systems in strands or wires. Depending on the particularity of the project, the preference of the client and the technical requirements either the BBR-CONA external prestressing system for strands, or the BBR-V system for wires can be chosen.

In the following the various BBR tendon types are briefly presented and described.

2.1 BBR CONA External for Strands

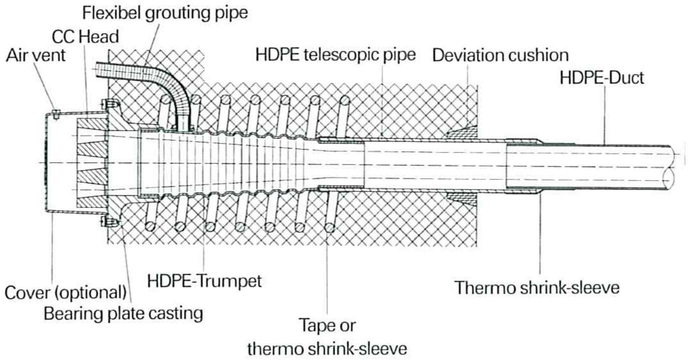
Two different BBR CONA External tendon types are offered by BBR. Within these tendon types some variations, resp. subtypes can be defined.



Special replaceable types
- using HDPE coated & greased strands (each strand is individually replaceable).
- using flexible corrosion inhibiting compound with plain strands.
- Completely electrically insulated cable using corresponding insulation plate under the anchor head.

A) Basic type

This type is shown in Figures 1 and 2.



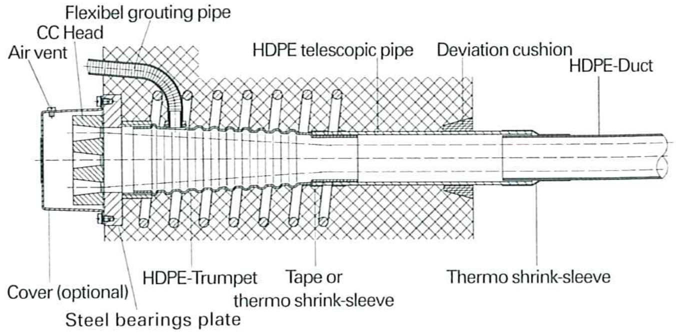


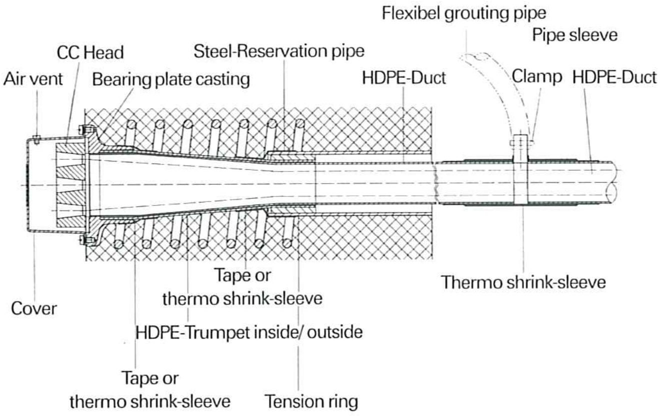
Fig. 1:
BBR CONA External basic type with bearing plate casting.

Fig. 2:
Alternative of basic type with fabricated steel bearing plate.

The basic BBR CONA External tendon is practically identical with the BBR Compact System for internal applications:

- The tendon is formed from plain 0.6" superstrands with ultimate strand capacities between 260.7 kN (ASTM 416-90) and 279 kN (Euronorm).
- The duct is from high density polyethylene and continuous from one anchorage to the other. The tendon sheathing passes freely through intermediate diaphragms, respectively deviators, whereby a metal or HDPE sleeve provides the required reservation-opening.
- A standard CONA Compact anchorage assembly consisting of anchor head, wedges, bearing plate casting and polyethylene trumpet safely transfers the prestressing forces to the end cross-beam (see Fig. 1).
- Alternatively to the bearing plate casting a fabricated steel bearing plate can be used (see Fig. 2).
- The tendon is filled with cement grout after it has been tensioned. As no double pipe is provided at the anchor points through the end -diaphragms a certain bond between tendon and structure is created which hinders the replaceability. Depending on requirements, the anchor heads may be protected by a cap, or alternatively the anchorage recess is filled with non-shrinkage concrete.

B) Replaceable type



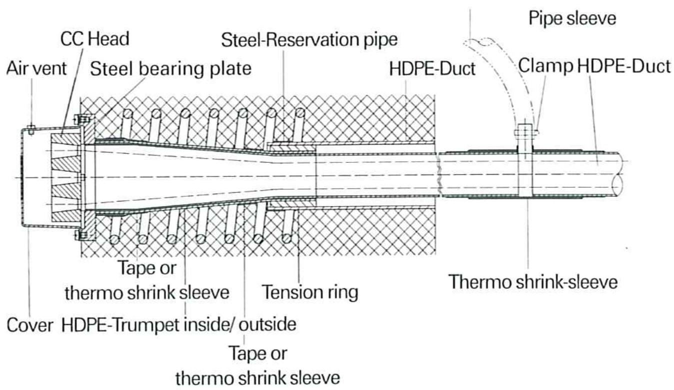


Fig. 3:
BBR CONA External, replaceable type with bearing plate casting

Fig.4:
BBR CONA External, replaceable type with fabricated steel bearing plate

As for the basic type the tendon is formed from plain 0.6" super strand with ultimate nominal breaking strength up to 279 kN per strand.

Alternatively plastic coated and greased monostrands can be used for multiple corrosion protection purpose. This alternate requires some slight dimensional changes of the bearing plates and trumpets. This particular type of tendon can be provided by BBR according requirements of specifications.

- The duct is from standard HDPE pipe, and continuous from anchorage to anchorage. The tendon sheathing passes freely through the intermediate diaphragms, whereby a metal or HDPE sleeve provides the required reservation.
- At the anchorages an internal HDPE trumpet with a pipe extension connects with the tendon sheating of the "free tendon length".
- The external HDPE trumpet and pipe provide the required reservation.
- A slightly adapted bearing plate casting or a special fabricated steel plate with conical (standard) or cylindrical transition trumpet is used together with a standard CONA Compact anchor head for safe transfer of the load to the concrete.
- After stressing, the tendon is generally injected with cement grout, but also a protection with organic flexible products, such as wax or petrolatum is possible.
- The internal and external trumpet in the anchorage zone allow the dismantling and replacement of the tendon.

  After HDPE-duct and cement grout have been locally removed, the strands of the tendon are slowly heated in the free length near the anchorage diaphragm and each strand individually flame-cut. After all strands have been cut the tendon can be removed in sections of suitable length. The last portion through the anchorage diaphragm is pulled through the external trumpet and the hole in the bearing plate.
- The anchorage is covered by means of a protection cap, wich is filled with a corrosion inhibiting compound.
- BBR CONA External replaceable tendons can easily be insulated against electrical stray-current by insertion of a high strength insulation plate between the anchor head and the bearing plate.

The strand tendon types are designed for easy and speedy installation on site.

The strands can either individually be pushed-in the HDPE sheathing, or pulled-in as a preassembled and compact bundle.

For special requirements and alternative detailing - use of plastic-coated and greased monostrand, electrical insulation, anchor types for particular applications - contact BBR Systems Ltd at Schwerzenbach/Zurich, Switzerland.

Preonzo Claro, Switzerland

Princes Highway Interchange, Melbourne, Australia

2.2 BBR-V External for Wires

Contrary to the site assembled BBR CONA External strand tendon, the BBR-V External System for wires is completely factory-assembled. It is used when very high quality standards are requested and replaceability is a requirement.

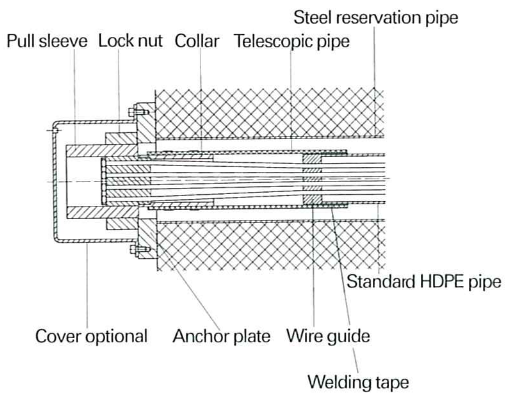


Fig. 5:
BBR-V External tendon for wires; stressable anchorage

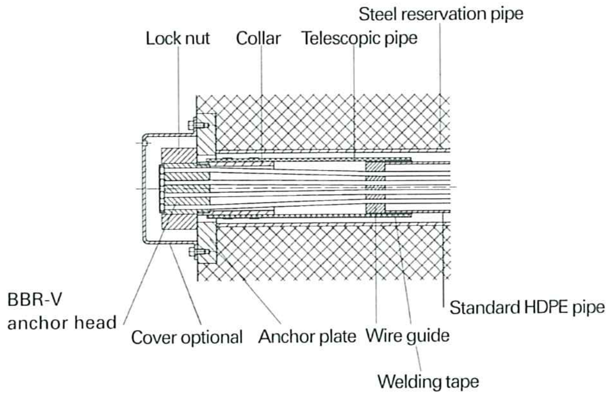


Fig. 6:
BBR-V External fixed anchorage

- The positive anchoring of each wire in the anchor block by means of the reliable BBR-V cold-formed button head is advantageous in case of vibration or impact.
- The BBR-V External wire tendons are completely assembled in the factory including the permanent corrosion protection, which consists of a flexible corrosion inhibiting compound. Therefore no grouting work is required on site.
- The tendons are delivered on drums or on coils and after installation stressed to the required force.
- The BBR-V External tendon remains destressable, restressable and replaceable at all times, if the structural detailing has properly considered these cases.

BBR-V External tendons for wires are composed of the following elements:

- Plain or galvanized high tensile wire dia. 7mm with an u.t.s. of 1670N/mm^2.
- The wire bundle is enclosed in a standard HDPE pipe PN 6.
- The voids are filled with a flexible corrosion inhibiting compound.
- The anchorage concept is the well-known BBR-V type, including anchor head, lock-nut and pull sleeve. The pull sleeve is used for stressable anchorages only.

2.3 BBR-CFP Tendons

For very particular applications, where corrosion or high stress amplitudes are of utmost concern, tendons from carbon fibres may be used.

Carbon-fibre-reinforced tendons can be offered by BBR.

- The BBR-CFP tendons have a very high strength up to 2700 N/mm^2, a high modulus of elasticity (similar to steel) and are very light (only about 1/5 of the steel).
- Furthermore, tendons from BBR-CFP wires are resistant to corrosion and have a very high fatigue resistance.

For information contact BBR Systems Ltd at Schwerzenbach/ Zurich, Switzerland

3. Tendon Characteristics and Main Dimensions

3.1 Tendon Characteristics

BBR CONA External

Number of strands dia. 0.6"		7	12	19	31
Tendon type		706	1206	1906	3106
Ultimate tensile force [1)]	kN	*1953	*3348	*5301	*8649
Stressing force at 0.8 u.t.s.	kN	*1562	*2678	*4241	*6919
Weight of strand bundle	kg/m	8.24	14.13	22.37	36.50

1) Based on Euronorm prEN 10138-1 1991, prestressing steels: dia. 0.6": guaranteed u.t.s. 1860 N/mm^2, strand area 150mm^2

* The effective forces depend on the specifications of the strand to be used and on the national code requirements to be applied.

BBR-V External

Tendon characteristics wires dia. 7mm

Number of wires dia. 7mm		31	42	52	61	82	102
Tendon type		31Ø7	42Ø7	52Ø7	61Ø7	82Ø7	102Ø7
Ultimate tensile force	kN	1992	2699	3342	3920	5270	6555
Stressing force at 0.8 u.t.s.	kN	1594	2159	2674	3136	4216	5244
Weight of strand bundle	kg/m	9.37	12.69	15.71	18.43	24.77	30.81

Remarks:

The BBR CONA External system has been designed on the use of 0.6 " strands with a nominal ultimate tensile force of 279 kN acc. to the relevant Euronorm. This is the most powerful 0.6" strand presently available therefore the forces indicated in the above table are based on the use of this type of prestressing strand.
It is obvious, that strands according to any accepted international standards e.g. ASTM A416, BS 5896 or others can be used. However, the tendon forces given have to be adjusted accordingly.

For economical reasons -cost for installation and stressing- BBR proposes only the use of 0.6" strand tendons. It has to be noted however, that 0.5" strand tendon units can be installed as well, with practically no dimensional changes of the tendon components.

It is also possible to use stressable couplings BBR CONA Compact, type K instead of stressable anchorages. The concept and main dimensions of this coupler type is found in the BBR Cona Compact brochure.

The BBR-V External tendon system is designed for the use of dia. 7mm wires with a nom. ultimate tensile strength of 1670 N/mm^2. The wires may be plain or galvanized. Depending on the clients requirements, the corrosion protection is applied in the factory in form of a flexible corrosion inhibiting product or on site by injecting the tendon with cement grout.

Depending on the clients requirements regarding replaceability and the procedure of replacement, the space requirements behind the anchorages and at the abutments have to be defined. BBR-V External tendons with soft corrosion protection can be removed as a complete unit and can possibly be reused, while BBR CONA External and grouted BBR-V External tendons have to be cut in sections for removal.

3.2 Main Dimensions

Cona External

A) Basic type

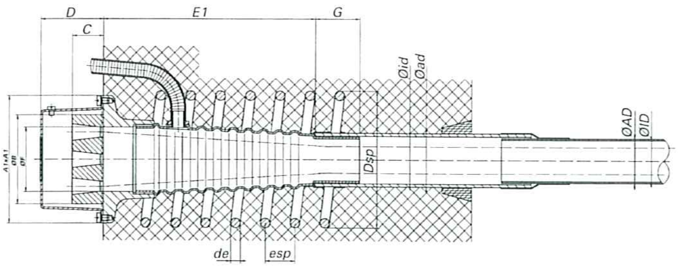


Fig. 7:
BBR-CONA External with bearing plate casting

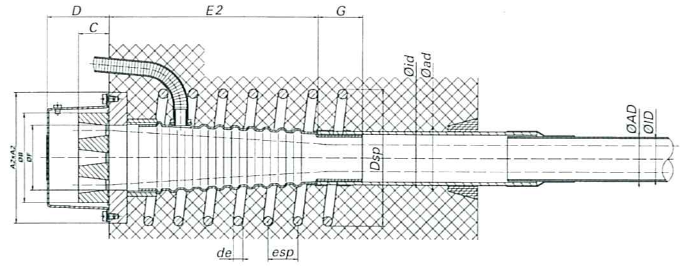


Fig. 8:
BBR CONA External with fabricated steel bearing plate

Table of dimensions (mm) (Fig. 7+8)

Type	A1xA1	A2xA2	øB	C	D	E1	E2	øF	G	AD/ID	ad/id	de	esp
706	215	220	150	52	105	355	350	109	75	75 / 66.4	90 / 79.8	16	50
1206	265	270	180	65	115	425	420	138	90	90 / 79.8	110 / 97.4	16	50
1906	335	345	230	80	130	511	505	178	80	110 / 97.4	140 / 114.4	20	50
3106	395	440	290	97	150	650	640	222	100	140 / 124	180 / 147.2	24	60

B) Replaceable type

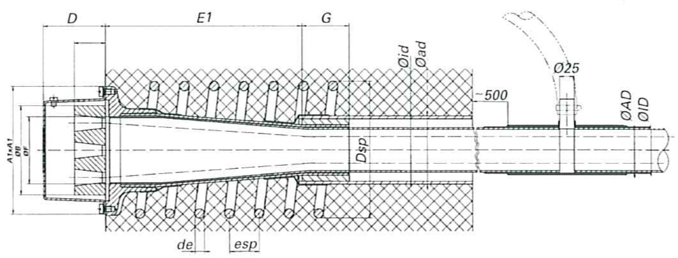


Fig. 9:
BBR-CONA External with bearing plate casting

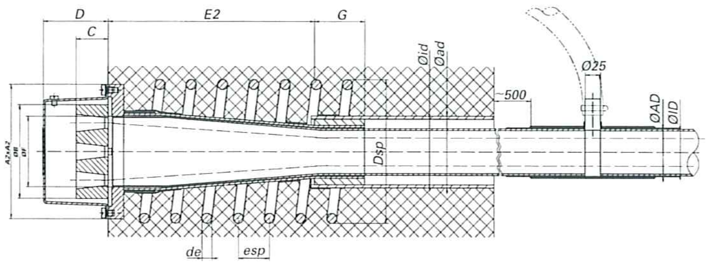


Fig. 10:
BBR-CONA External with fabricated steelbearing plate

Table of dimensions (mm) (Fig. 9+10)

Type	A1xA1	A2xA2	øB	C	D	E1	E2	øF	G	AD/ID	ad/id	de	esp
706	215	220	150	52	105	275	280	113	80	75/ 66.4	115/105	16	50
1206	265	270	180	65	115	548	555	144	80	90/ 79.8	130/120	16	50
1906	335	345	230	80	130	745	760	184	80	110/ 97.4	150/140	20	50
3106	395	440	290	97	150	910	930	230	80	140/ 124	180/170	24	60

C) BBR-V External Tendon

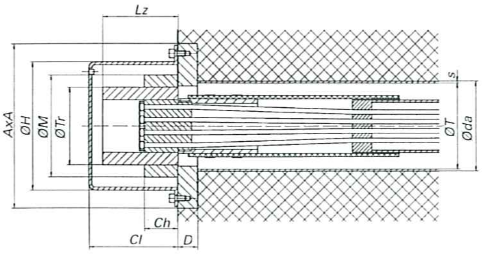


Fig. 11:
BBR-V External stressable anchorage

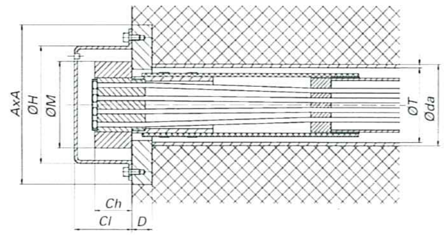


Fig. 12:
BBR-V External fixed anchorage

Table of dimensions for stressable anchorages (mm) (Fig. 11.)

Type	AxA	D	Ch	Cl	ØH	Lz	ØM	ØTr	Øda	s	ØT
31Ø7	250	30	50	134	195	114	155	118 x 5	140	2.5	135
42Ø7	290	40	60	148	215	128	175	132 x 5	155	2.5	150
52Ø7	320	45	65	168	230	148	190	144 x 5	165	2.5	160
61Ø7	350	50	70	180	250	160	210	158 x 5	190	5	180
82Ø7	400	60	80	206	280	186	240	185 x10	210	5	200
102Ø7	450	70	85	222	310	202	270	210 x10	254	6.5	241

Table of dimensions for fixed anchorages (mm) (Fig. 12.)

Type	AxA	D	ØM	Ch	Ødo	ØT	s	Cl	ØH
31Ø7	235	30	133	55	110	106	2	95	173
42Ø7	280	40	152	62	130	125	2.5	102	192
52Ø7	310	45	169	72	145	140	2.5	112	209
61Ø7	340	50	175	78	145	140	2.5	118	215
82Ø7	390	60	198	91	160	155	2.5	131	238
102Ø7	430	70	221	100	190	180	5	140	261

For special sizes of CONA or BBR-V External tendons please contact Bureau BBR Ltd.

3.3 Space Requirement for Stressing and Replacement of Tendons

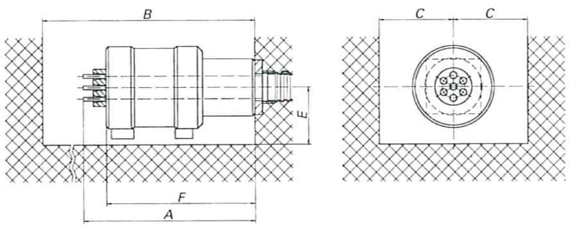


Fig. 13:
Space requirement for stressing

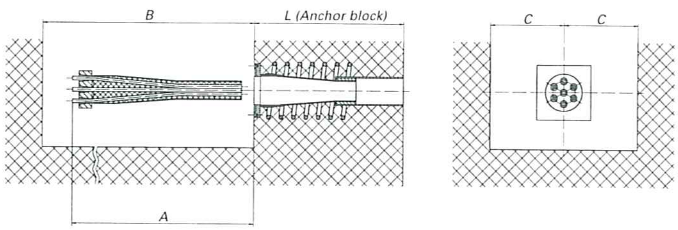


Fig. 14:
Space requirement for replacement

Table of dimensions (mm) (Fig.13)

Type	A	B	C	E	F
706	880	1600	330	260	750
1206	945	1735	400	330	810
1906	1040	1900	500	430	890
3106	1220	2310	620	550	1050

Table of dimensions (mm) (Fig. 14)

Type	A	B	C
706	L+280	A +750	330
1206	L+295	A +790	400
1906	L+310	A +860	500
3106	L+330	A+1090	620

4. Deviators

4.1 Description

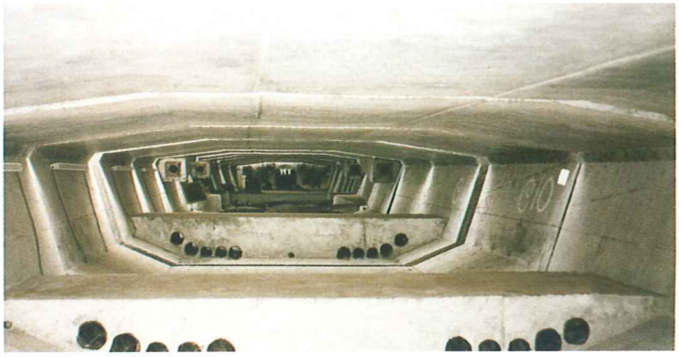
For deviators a lot of different solutions can be found. On one side in the choice of the shape, on the other side in the selection of the materials. This section shall give some main guidelines for the design of the deviators and show some of the most common solutions. Deviators are integral parts of the structure and have to satisfy in principal following requirements:

- resist the transversal (radial) and longitudinal forces generated by the tendon and transfer the same safely to the structure.
- Realize a smooth tendon profil (geometry) without unacceptable angular changes (kinks) and untolerable deformations of the tendon shape (oval deformation).
- In case the tendon has to be replaceable the deviator has to be designed in such a way, that no damages are caused to the structure during the replacement of the cable.

Two main types of deviators can be classified.

Single tube deviators:

This type is mostly used for non replaceable tendons. The deviator tube is part of the tendon conduit. Most often steel pipes are used for this type. The PE-duct of the tendons is connected to both ends of the pipe.



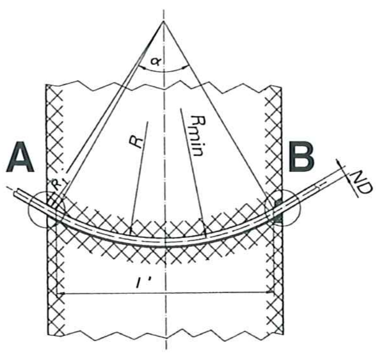
View of deflector beams at centre of bridge span

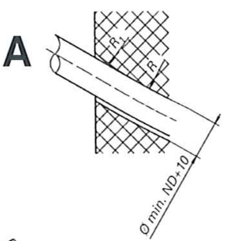
Double tube deviators:

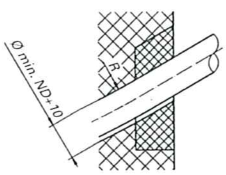
This type is mostly used for replaceable cables. The exterior tube is an integral part of the deviator independent from the cable. The interior tube is part of the tendon conduit. Very often steel pipes are used for the exterior tube. The interior tube is commonly the standard HDPE-duct.
Whatever solution is used, the chosen materials should consider following aspects:

- precise geometry of deviator (fabrication tolerances, rigidity during casting)
- long term resistance to contact pressure of tendon.
- corrosion protection.

4.2 Main Dimension for Deviators







B

Fig. 15: General dimensions

Table of dimensions (mm) (Fig. 15)

Typ CONA	706	1206	1906	3106
Typ BBRV	31ø7	42ø7/51ø7	61ø7/82ø7	102ø7
*R_{min} [m]	2.0	2.5	3.0	4.0
ND [mm]	90	110	140	180
R_1 [m]	1.0			
∝	Deviation angle			
l'	Theoretical connecting			

Above the minimum Radius is in accordance with the SETRA publication "External Prestressing". It is recommended to chose an effective radius of about double the value indicated above, if the angular change of the tendon and the deviator block dimensions permit.

In the deviator zone the cable geometry is a segment of a circle with radius R> Rmin.. The min. radius Rmin. for the CONA External tendon can be found in the table above. To assure a smooth tendon profile at both exits of the deviator, two basic solutions are possible:

1) Bell mouth opening (see detail A). The deviator tube is widened atboth ends in order to create a transition radius R1, which is smaller then the deviator radius R. The min value for R1 is given in the table above.
2) Exit with damping devices (see detail B). Both exits of the deviator tube are damped by means of elastic cushions in form of a rubber insert (Neoprene or other similar material).

4.3 Possibles Solutions

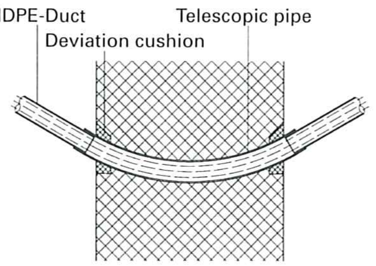


Fig. 16:
Deviator typical for non replaceable tendons

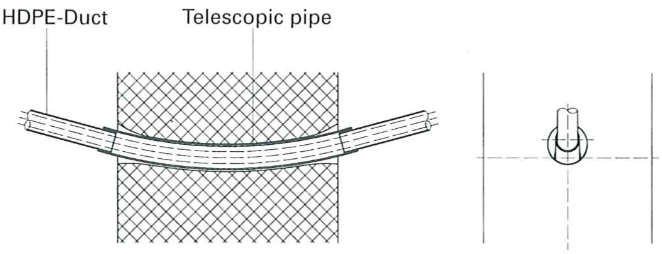


Fig. 17:
Deviator typical for replaceable tendons

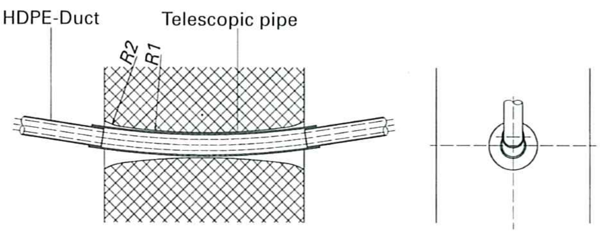


Fig. 18:
Bell mouth type, typical for tendons used in precast segmental bridges

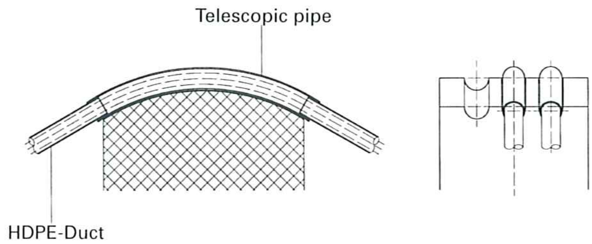
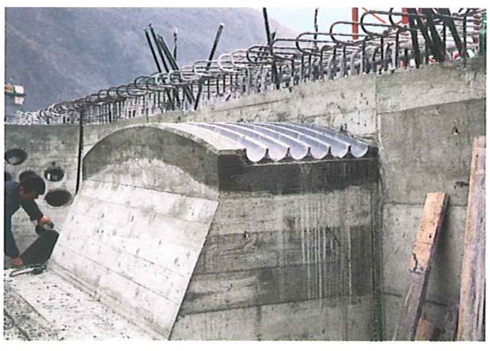


Fig. 19:
Open saddle

Fully stressed BBR CONA External tendons

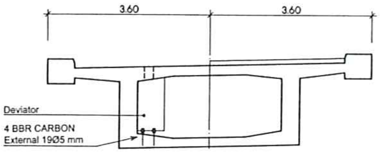
View of coupled and fully stressed external tendons



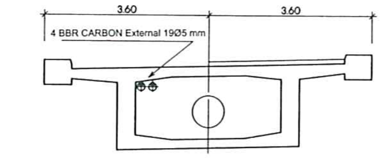
Open Saddle

5. Strengthening with BBR CARBON PT Cables Pont sul Rì di Verdasio Ticino, Switzerland

An internal prestressing tendon of this 69 m long twin-span box girder - corroded due to de-icing salts - was replaced by four external CFRP tendons arranged in a polygonal layout at the inner face of the affected concrete web. Extensive tests carried out at the Swiss Federal Laboratories for Materials Testing and Research laid the foundations for this first full scale application of deviated CFRP cables.
A proposal submitted by BBR involving the use of CFRP tendons was accepted. The required 4 CFRP tendons consisted of 19 wires with dia. 5 mm each. Their installation required the construction of 2 additional concrete deviator diaphragms, monolithically connected to the web. In the upper part of the existing diaphragm over the middle pier, 2 steel deviators were placed in a specially drilled opening, each containing 2 CFRP tendons. Finally 4 openings were drilled in each of the end diaphragms in order to permit anchoring of the tendons.
Stressing of the tendons was done at 0.65 u.t.s with a posttensiong force of 600 kN per tendon.



Cross section at mid-span



Cross section over the middle pier

Owner:
Dipartimento del Territorio
Bellinzona, Ticino, Switzerland

Designer:
Winiger, Kränzlin & Partner,
Consulting Engineers Ltd,
CH-8004 Zurich

CFRP Tendons:
Joint Venture BBR-EMPA,
Dübendorf

Stressing operations:
Stahlton AG, Zurich
(BBR Swiss Licensee)

6. BBR Sevices:

In connection with the application of external prestressing, BBR Systems Ltd and their local representatives can provide the following supplies and services:

- Full technical assistance and consulting services.
- Feasibility studies and project evaluation.
- Preliminary and detailed design of complete structures or parts thereof.
- Detail working drawings of the post-tensioning system.
- Design modifications and alternative proposals.
- Construction engineering and design of temporary works such as launching trusses, formwork travellers, incremental launching equipment and load handling systems.
- Plant lay-out.
- Material specifications, quality control and surveillance.
- Supply of prestressing materials.
- Complete prestressing operations -tendon installation, stressing and grouting.
- Apply or rent of prestressing equipment.
- Site supervision by specialists and project management.
- Supply of launching trusses, formwork travellers, incremental launching equipment and load handling systems.
- Package deals, comprising engineering services, supplies, supervision and labour on site, including supply of bearings and construction joints.
- Supply and installation of prestressing bars.

*BBR and CONA are registered trade marks.

Local agency:

BBR Systems Ltd
Bahnstrasse 23
P.O. Box
CH-8603 Schwerzenbach/Zurich
Switzerland

Tel. ++41 1 806 80 60
Fax ++41 1 806 80 50
bbr_switzerland@csi.com