Prethodno napregnute konstrukcije

Predavanja

2021/2022

PIV – Sistemi i tehnologija

Tehnologija i postupci prethodnog naprezanja

Prethodno naprezanje prethodnim zatezanjem – na stazi

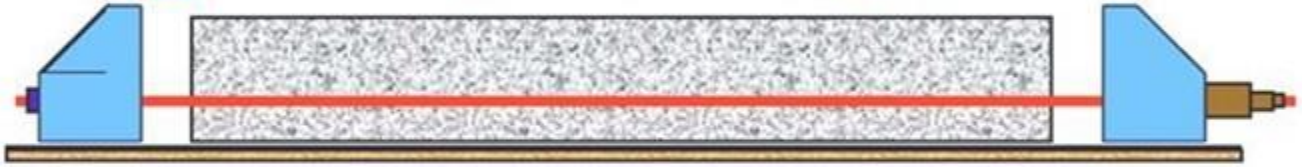
Na kraju staze za prethodno naprezanje postavljene su hidrauličke prese za zatezanje užadi

Hiodrauličke prese rade na principu pritiska ulja. Sila koja se aplicira presom mjeri se pomoću mjerača pritiska ulja ili posebnog mjerača sile.

Redosljed operacija pri prethodnom naprezanju na stazi

1. Sidrenje užadi, postavljanje presa, zatezanje čelika

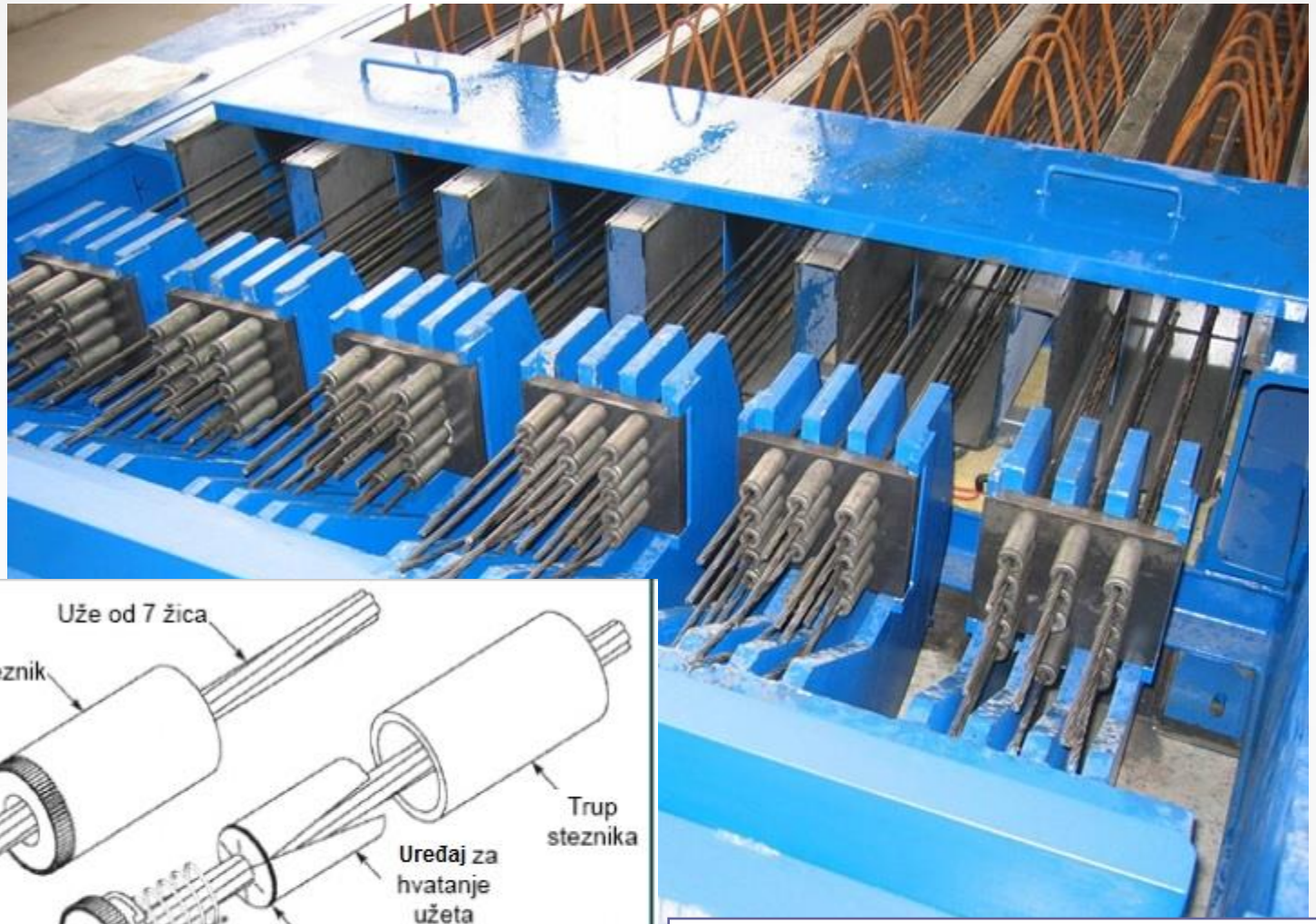
2. Betoniranje konstruktivnog elementa



3. Otpuštanje užadi i prenos naprezanja

Nakon prenosa naprezanja sa užadi na beton dolazi do elastičnog skraćenja elementa.
Ukoliko su kablovi postavljeni ekscentrično element će dobiti negativan ugib - nadvišenje.

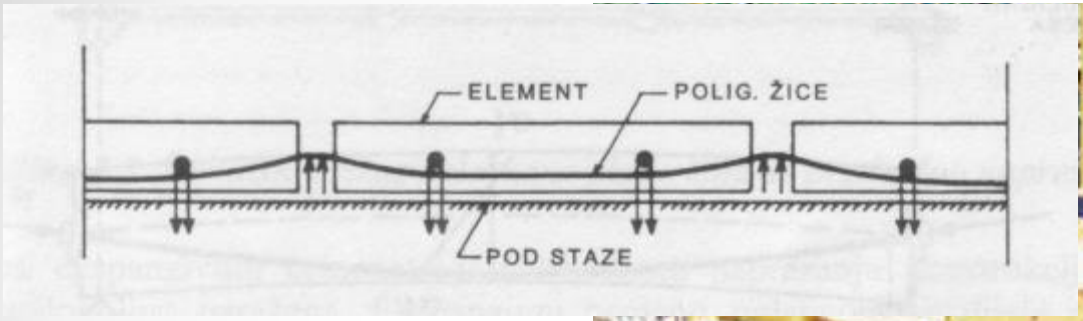
Sidrenje kod prethodnog naprezanja na stazi

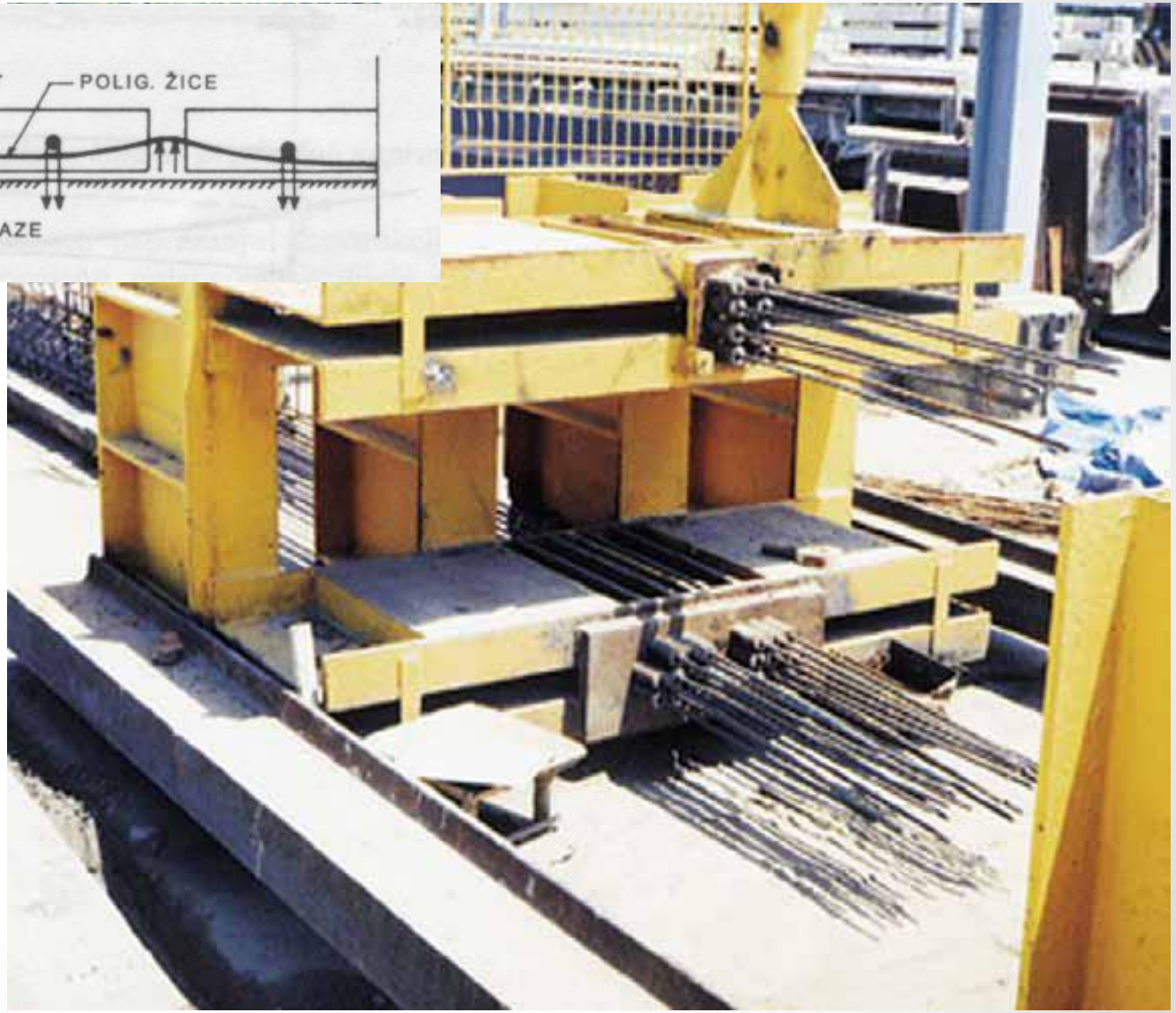


Koriste se uređaji za sidrenje koji se jednostavno otpuštaju

Staza za prethodno naprezanje sa postavljenim užadima i mekom armaturom

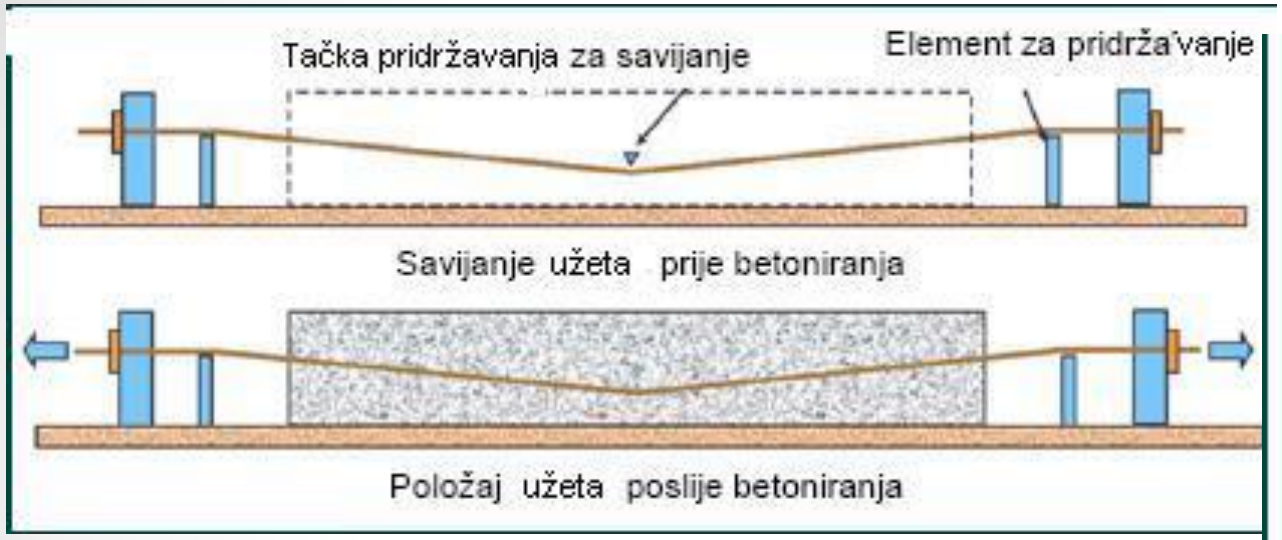
Kod elemenata prethodno napregnutih na stazi često se predviđa postavljanje užadi (žica) po poligonalnoj trasi.

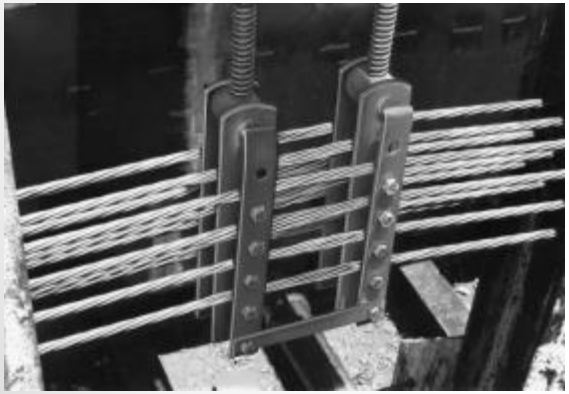


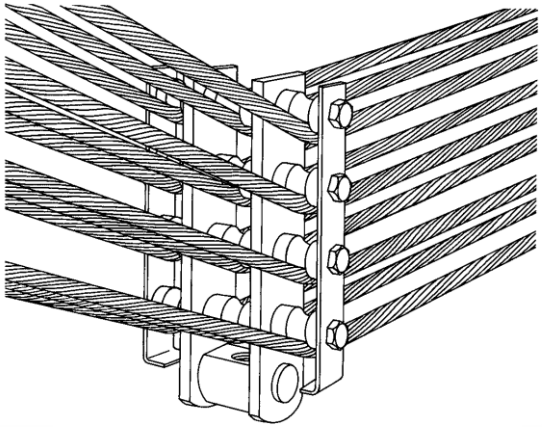


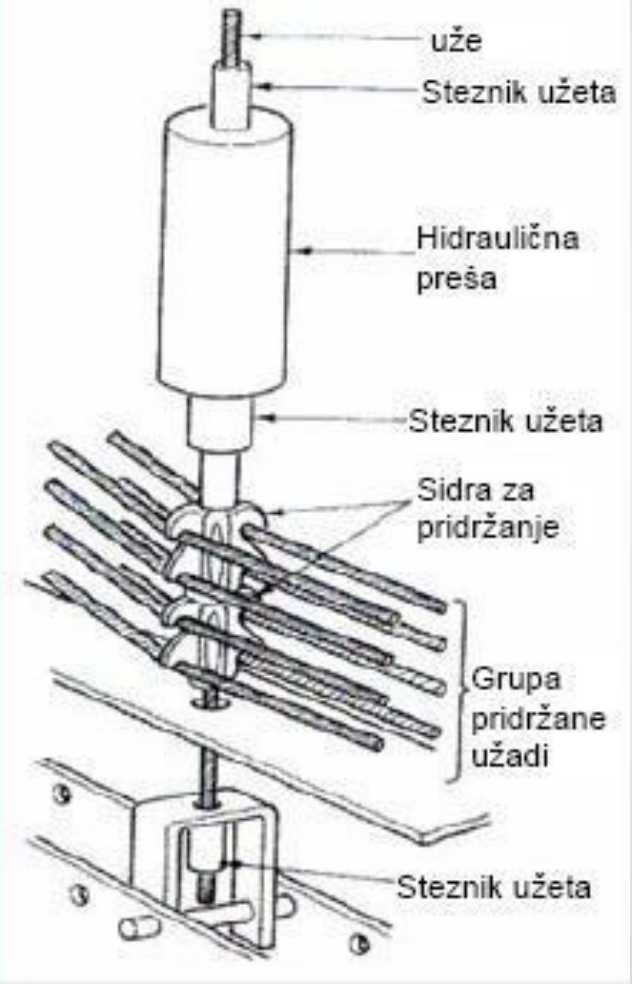
Poligonalni tok užadi (žica) je poželjan u cilju boljeg prilagođavanja efekata prethodnog naprezanja konstruktivnim uslovima.

Užad se usmjeravaju po predviđenoj trasi korišćenjem posebnih uređaja za pridržavanje užadi.





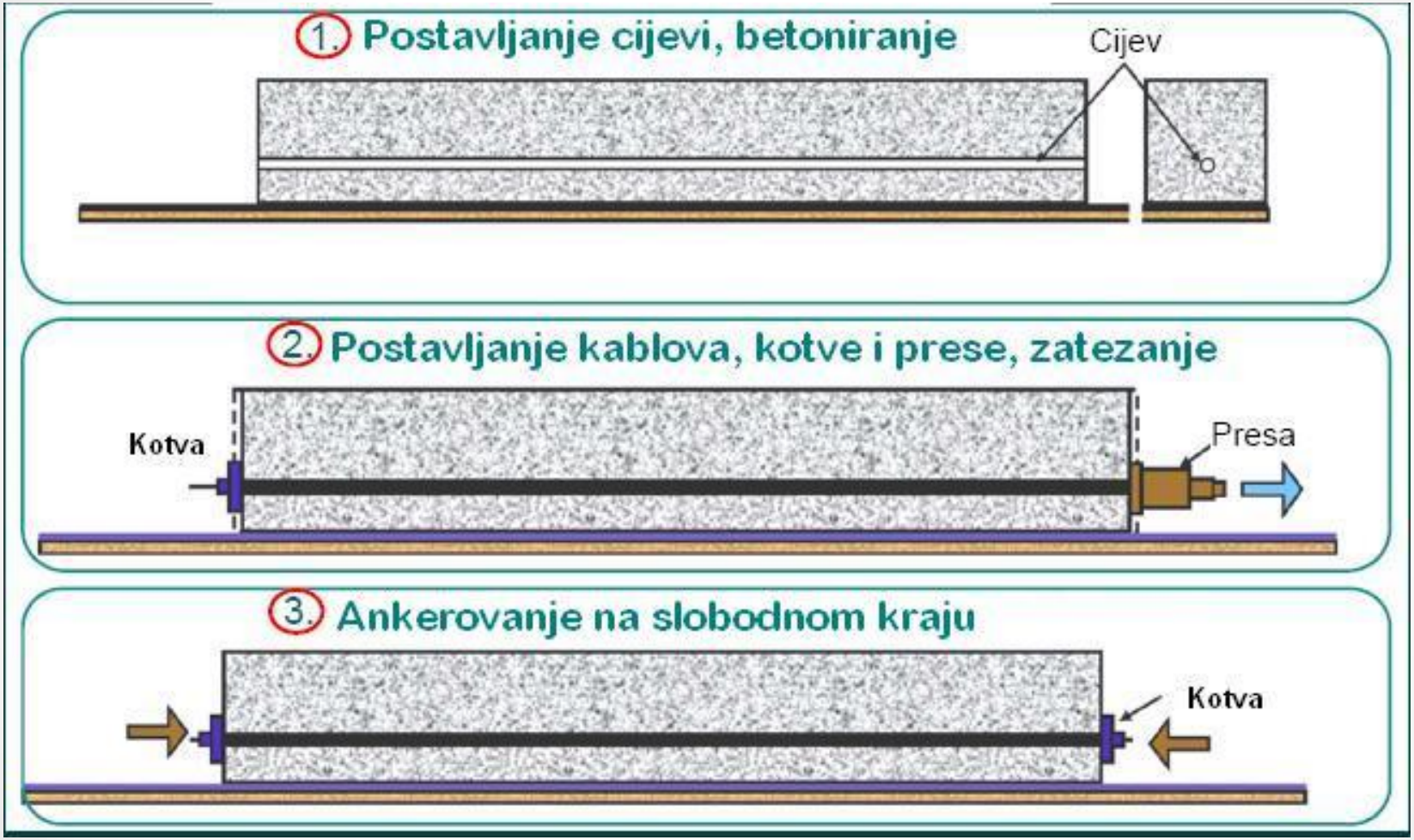




Uređaji za pridržavanje (skretanje) užadi

Prethodno naprezanje naknadnim zatezanjem

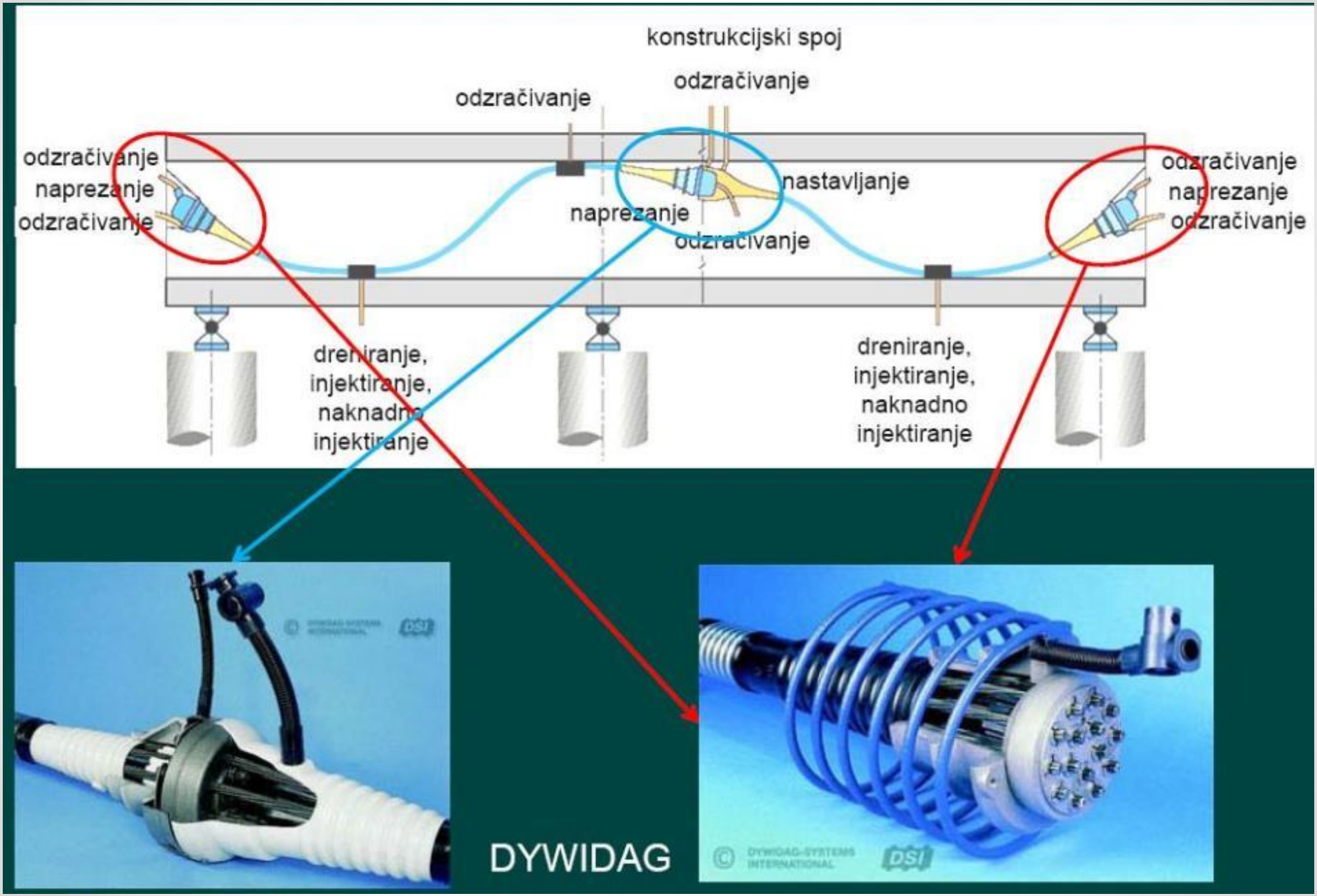
Redosljed operacija



Operacije i postupci pri prethodnom naprezanju naknadnim zatezanjem

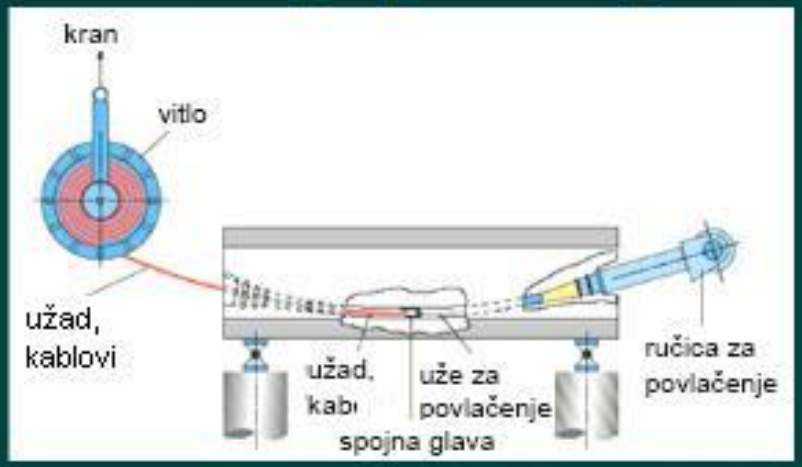
- U betonskom elementu se postavljaju zaštitne cijevi duž projektovane putanje – trase kablova
- Kroz otvore (cijevi) se provlače kablovi za prethodno naprezanje
- Zatezanje kablova se vrši nakon očvršćavanja betona
- Ankerovanje kablova se vrši pomoću kotvi
- Kotve mogu biti fiksne i pokretne
- Fiksna kotva može biti na jednom kraju, dok na drugom mora biti pokretna, za zatezanje kabla. Moguće je postaviti pokretne kotve na oba kraja kabla.
- Nakon zatezanja i ankerovanja kablova vrši se injektiranje – popunjavanje prostora između cijevi i kabla radi zaštite kabla od korozije i monolitizacije presjeka

Djelovi sistema za naknadno zatezanje

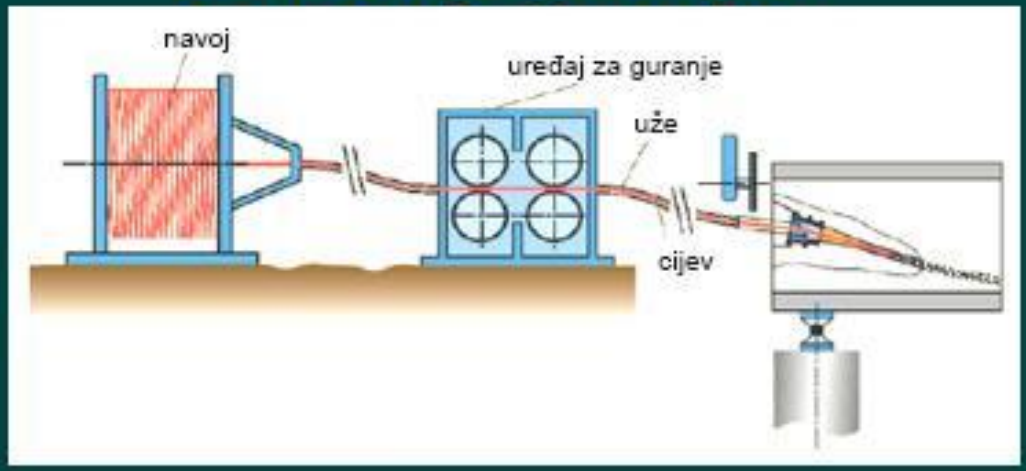


Uvlačenje kablova - užadi

Uvlačenje potezanjem



Uvlačenje guranjem



Zatezanje kablova vrši se pomoću hidrauličkih presa.

Presa Jack HoZ 4,000

Hidraulička pumpa

Presa zajedno sa hidrauličkom pumpom služi za zatezanje kablova.

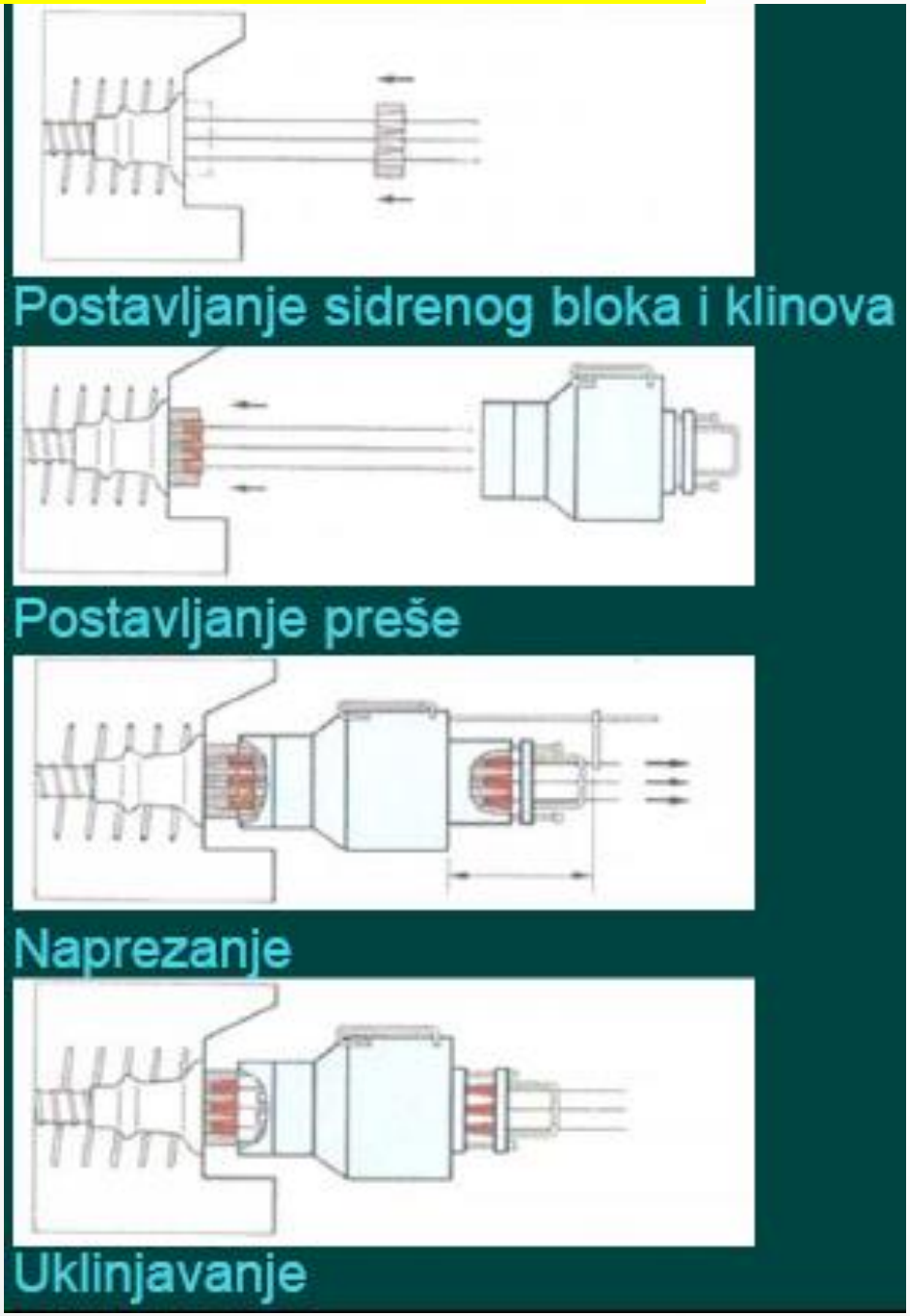
Kapacitet prese DYWIDAG je od 250-9750kN.

Hidrauličkom pumpom se kontroliše pritisak ulja u presi, na kojoj postoji ventil za zaštitu od preopterećenja.

Redosljed operacija pri zatezanju

Zatezanje kablova može da se vrši sa jednog ili sa oba kraja.

Ukoliko se zateže samo sa jednog kraja na drugom kraju se postavlja fiksna kotva.



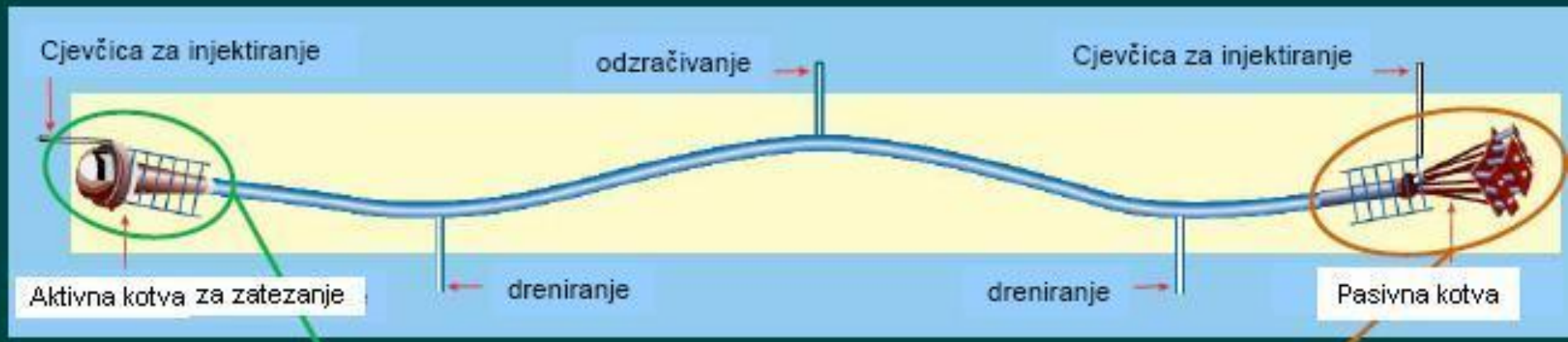

Postavljanje sidrene glave


Postavljanje preše


Naprezanje, mjerenje, uklinjavanje


Injektiranje

Sidrenje i injektiranje

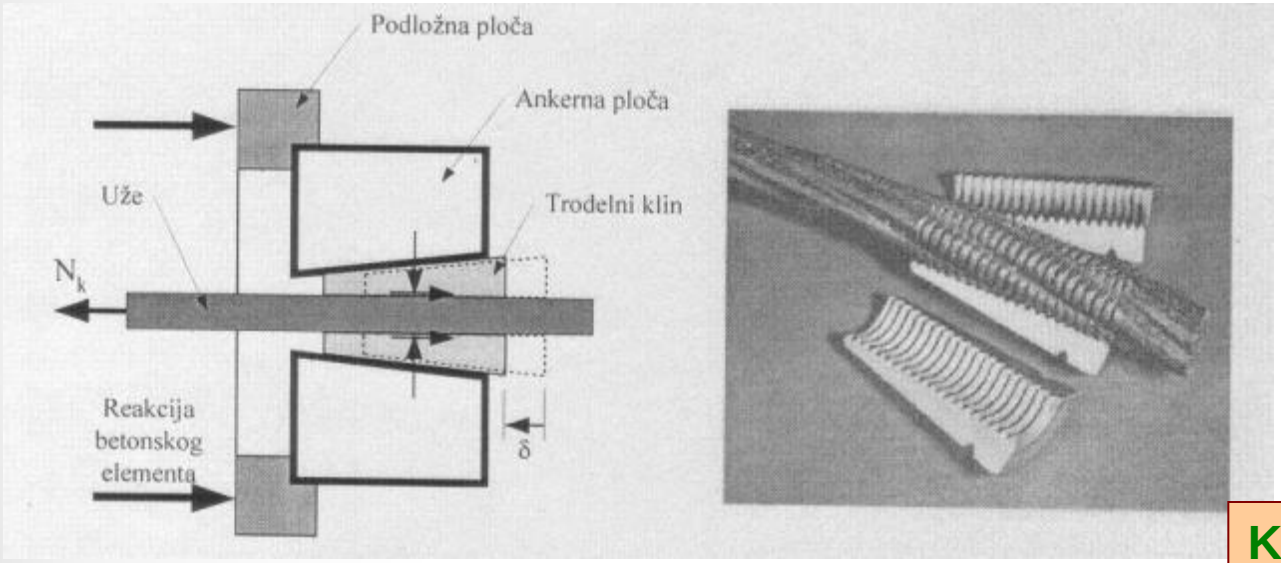


VSL

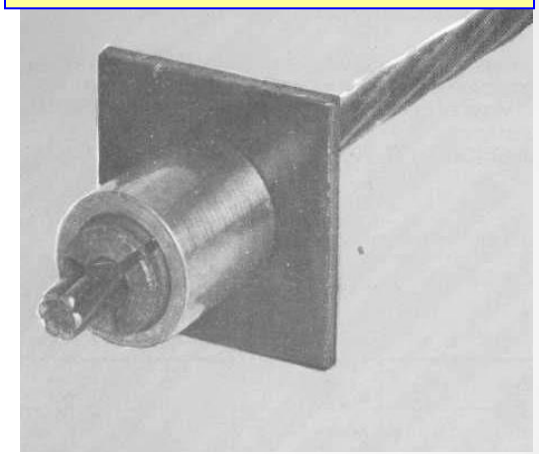
Sidrenje kablova kod naknadnog zatezanja se vrši pomoću:

- Kotve sa klinovima (kod većine sistema)
- Kotve za žice sa glavicama oblikovanim u hladnom stanju (BBR sistem)
- Kotve sa navojima za sidrenje šipki (DYWIDAG sistem)

Princip zaklinjavanja

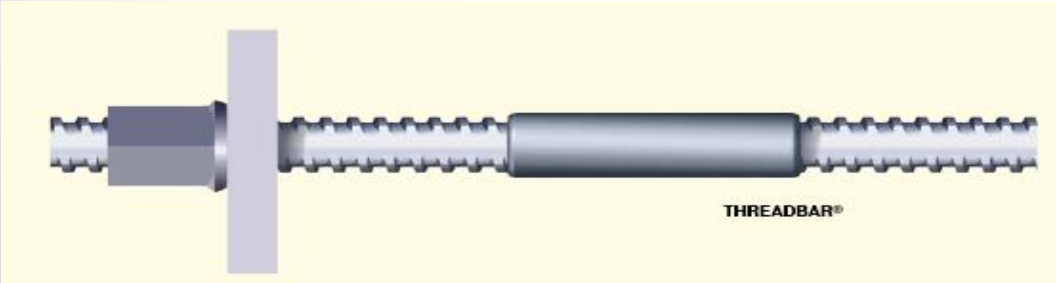


Kotva sa klinom



Kotva za žice sa glavicama

Sidrenje šipke pomoću navoja i matice



Vrste kotvi

- aktivne (normalne, pokretne)
- fiksne (nepokretne)
- nastavne kotve.

Fiksna kotva

Aktivna (normalna) kotva sa klinovima

Kablovi savremenih sistema za prethodno naprezanje se sidre pomoću kotve sa klinovima.

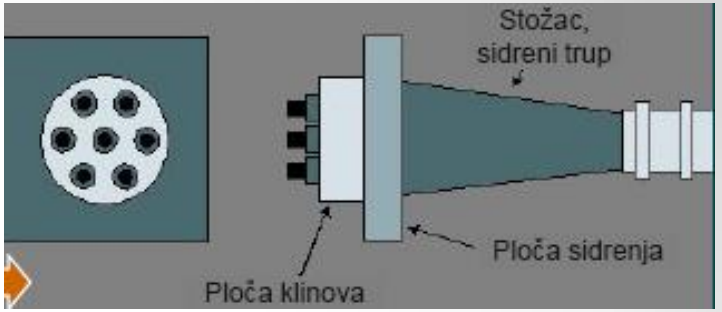
Aktivna kotva BBR sistema

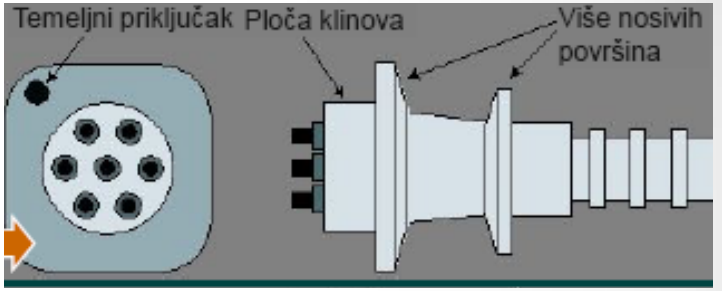
Fiksna kotva

Nastavna kotva BBR sistema

Aktivna kotva se postavlja na mjestu zatezanja kablova. Elementi aktivne kotve:

1. Klin (trodjelni)
2. Čaure (za pojedinačno ukotvljavanje užadi)
3. Ankerne ploče (sa više konusnih otvora)
4. Ravna podložna ploča (square plate)
5. Podložna ploča sa rebrima (bearing trumplate)
6. Konusni nastavak (trumpet)
7. Ravna podložna ploča se koristi za sidrenje u pločastim elementima, dok se za sidrenje većih kablova koriste ploče sa rebrima, koje imaju više površina za prenos sile.

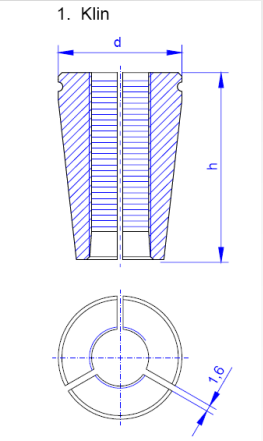




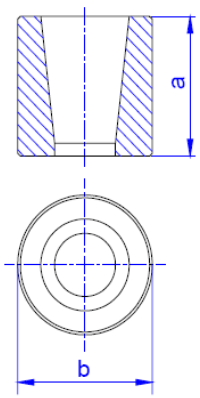
Fiksna (nepokretna) kotva se koristi umjesto normalne kotve u slučajevima kada postoje konstruktivne mogućnosti i kada je jedan kraj nepristupačan za prethodno naprezanje. Konstruktivne mogućnosti podrazumijevaju dovoljnu masu nosača da se kotva može montirati i ako se puna sila prethodnog naprezanja može uvesti na rastojanju "***d*** "od kraja kotve.

Nastavna kotva služi za nastavljanje i produžavanje kablova. Primjenjuje se kod kablova koji nijesu prethodno napregnuti, koji su djelimično prethodno napregnuti kao i kod potpuno prethodno napregnutih kablova. U prva dva slučaja na dužinu "***a***" koja je data u tablici mora se dodati izduženje kabla koji se nastavlja.

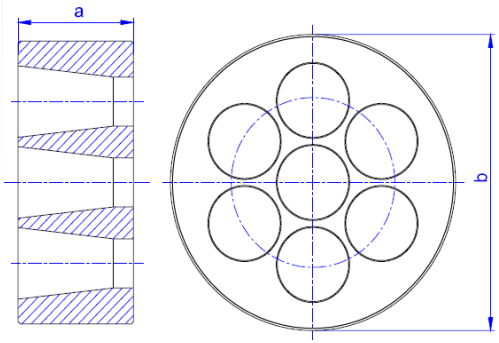
1. Klin



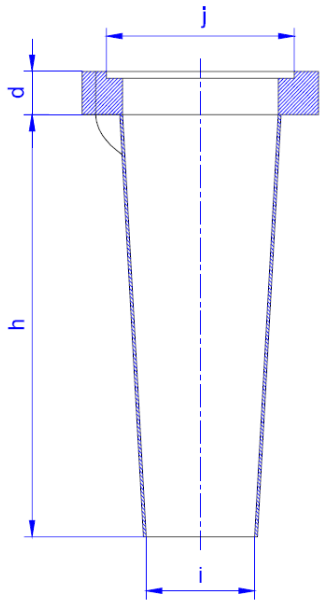
2. Čaura



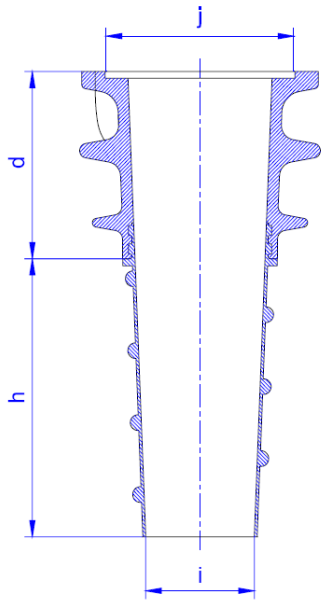
3. Ankerna ploča

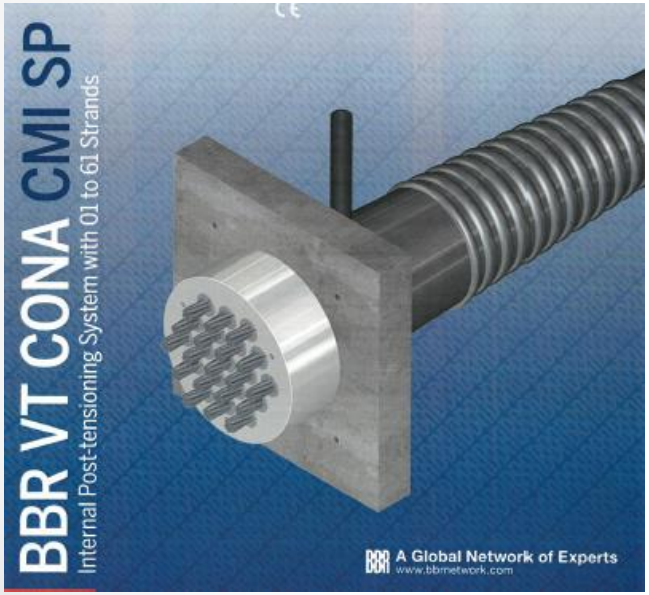


4. Ravna podložna ploča

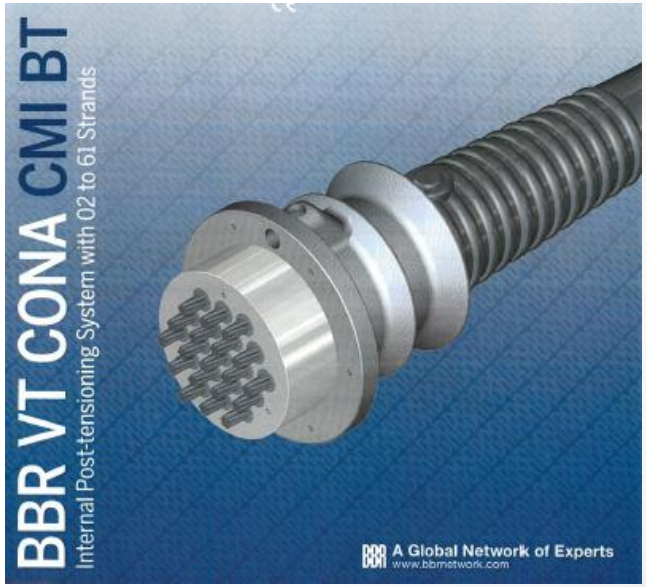


5. Livena podložna ploča





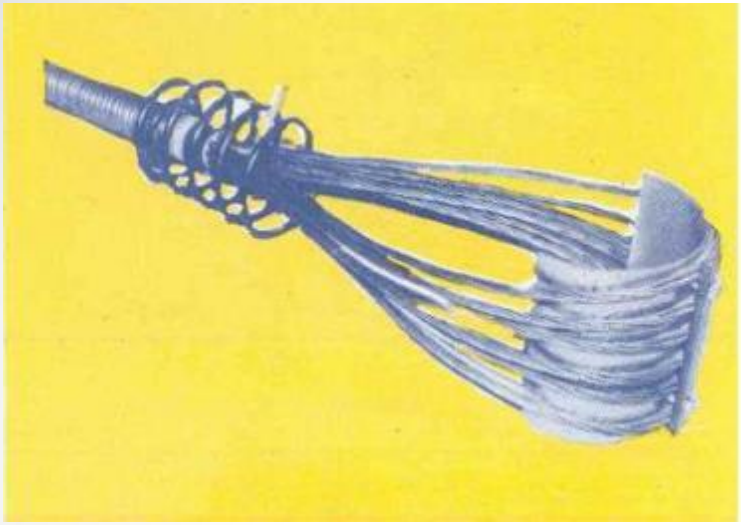
Normalna kotva sa ravnom podložnom pločom



Normalna kotva sa livenom podložnom pločom

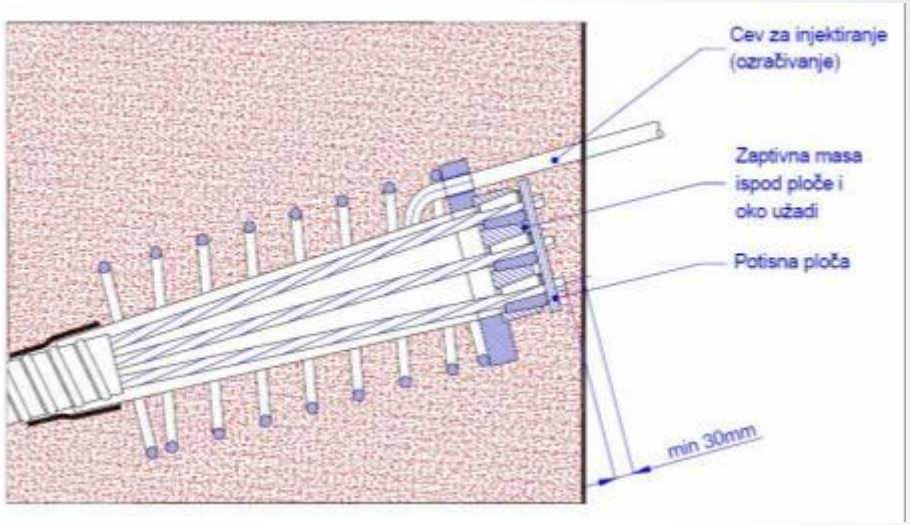
Fiksne (nepokretne) kotve

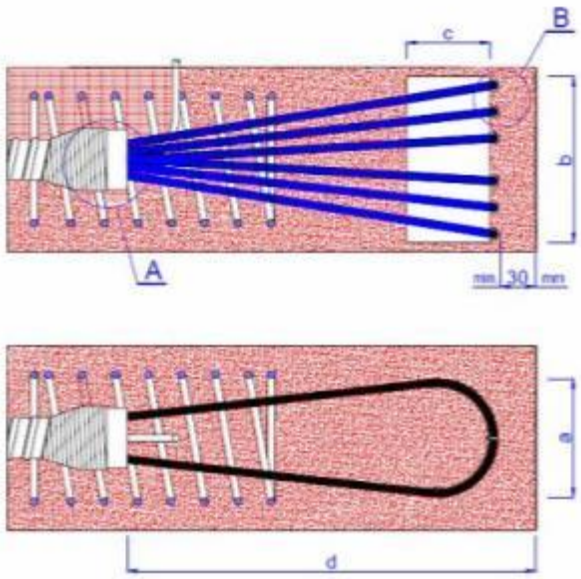
sa previjanjem užadi

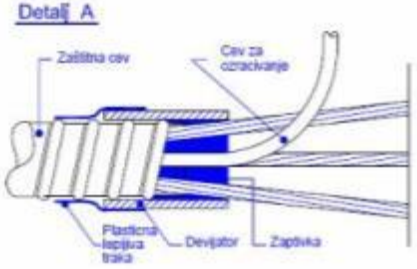


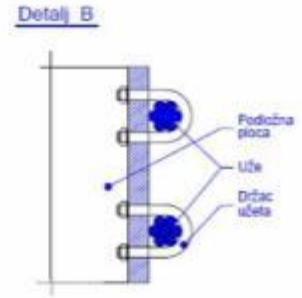
1. Skica fiksne kotve sa previjanjem užadi

izrađena od normalne kotve





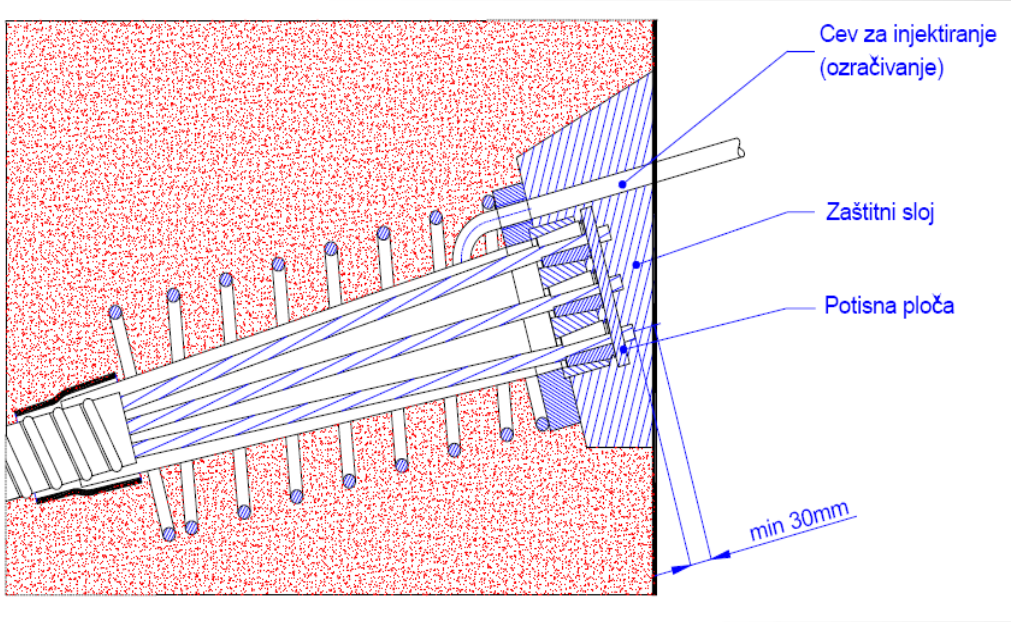




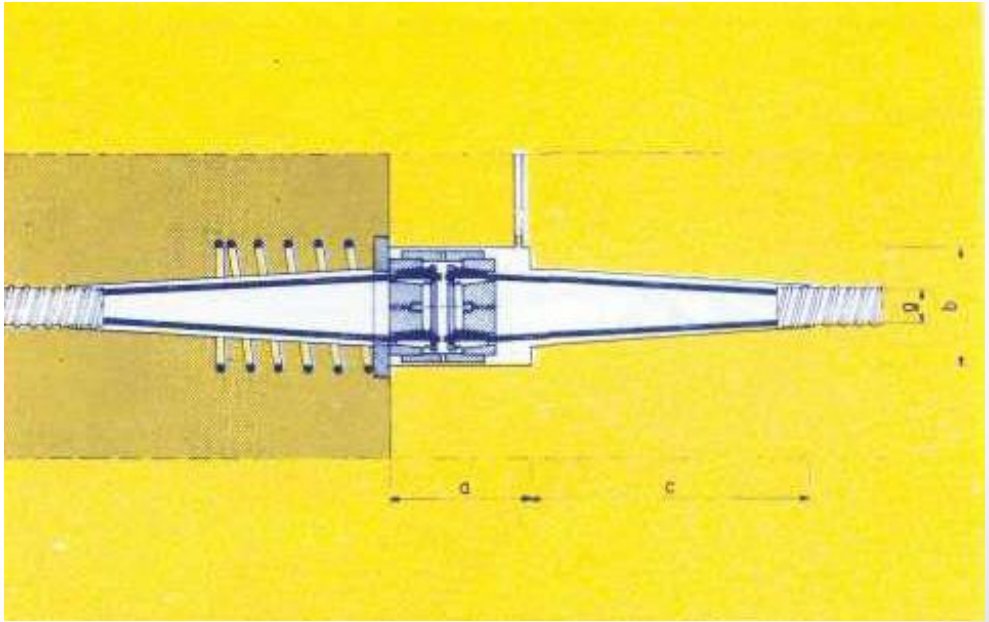
Fiksna kotva izrađena od normalne kotve primjenjuje se kad je konstrukcija nepristupačna sa jedne strane a silu prethodnog naprezanja je neophodno unijeti od samog čela nosača

Pasivna kotva

Pasivna kotva se primjenjuje kad je moguće prethodno naprezanje izvesti samo sa jedne strane i/ili kad je pristup sa jedne strane ograničen. Izrađuje se kao normalna kotva sa skraćenim kablovima.

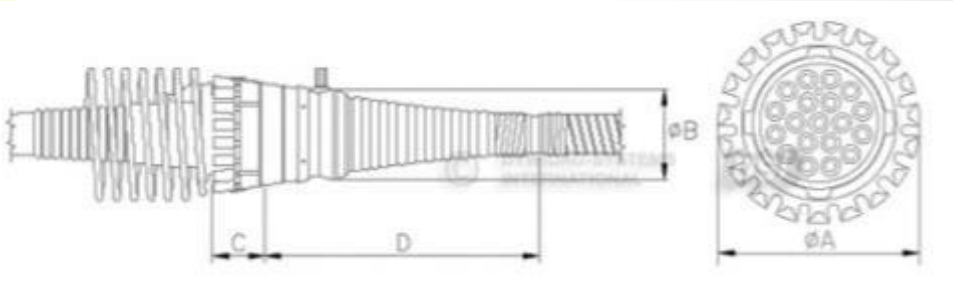


Nastavljanje kablova



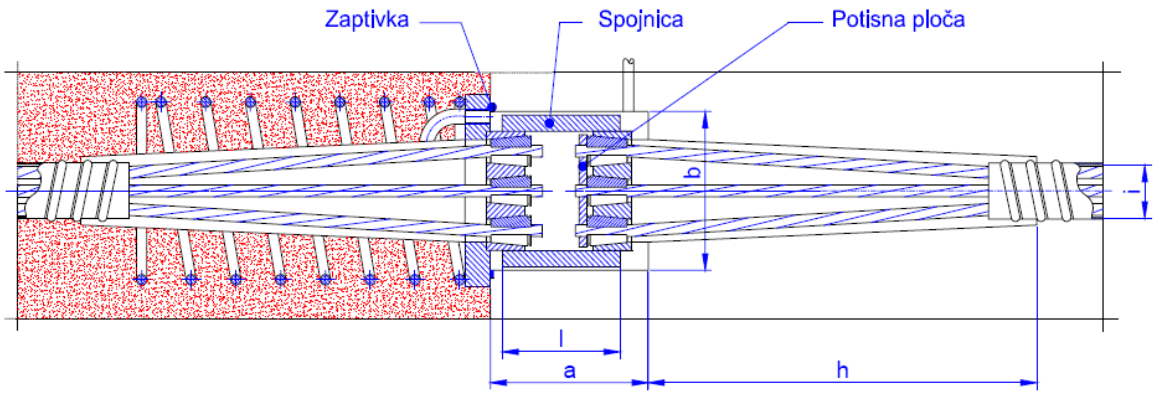
Nastavljanje kablova

Nastavna kotva BBR sistema za više užadi



1. Skica nastavne kotve

Nastavna kotva



Nastavna kotva za jedno uže (monostrand)

Coupler H
CONA CMM SINGLE

Provjera položaja cijevi – rebraste z.c.

Glatke zaštitne cijevi

Uvlačenje pojedinačnih kablova

Podužne i poprečne cijevi

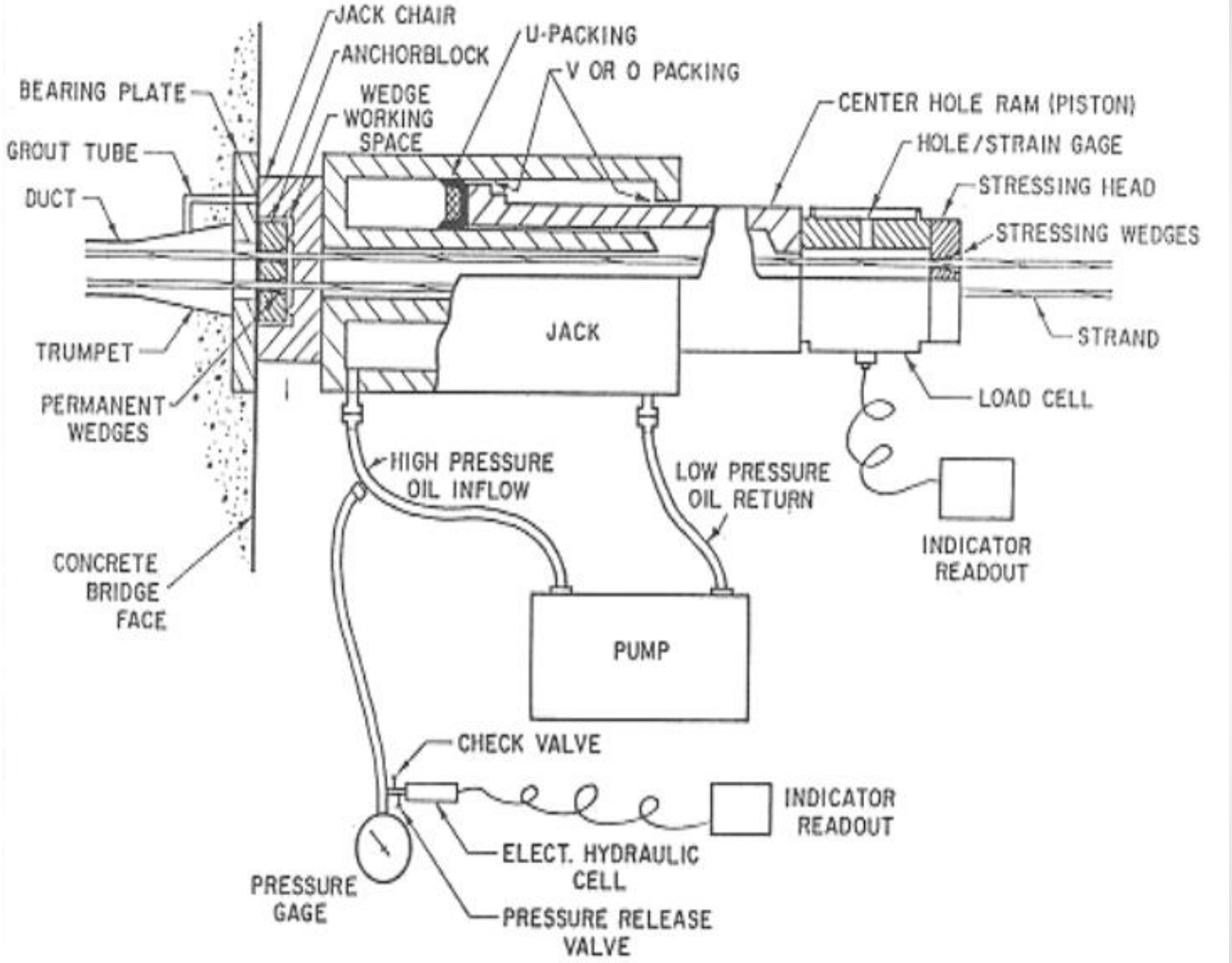
Umetanje klinova

Klinovi u ankernoj ploči

Postavljanje uređaja za sidrenje i prese

Izgled ankernog bloka

Šematski prikaz djelova sistema za naknadno zatezanje



Injektiranje kablova

Oprema za spravljanje i pumpanje injekcione smješe

Mixing and pumping equipment

Odzračivanje

Venting operation

Trajnost konstrukcija sa naknadno zategnutim kablovima sa spojem u velikoj mjeri zavisi od uspješno obavljenog injektiranja.

Očvrsla cementna pasta stvara vezu između zategnutog elementa i betona, obezbjeđuje dugotrajnu korozionu zaštitu čelika za prethodno naprezanje.

Priključenje dovoda injekcione smješe

Sistemi prethodnog naprezanja

BBR sistem
DYWIDAG sistem
VSL sistem
FREYSSINET-ov sistem
MAGNEL-ov sistem

Uvodne napomene

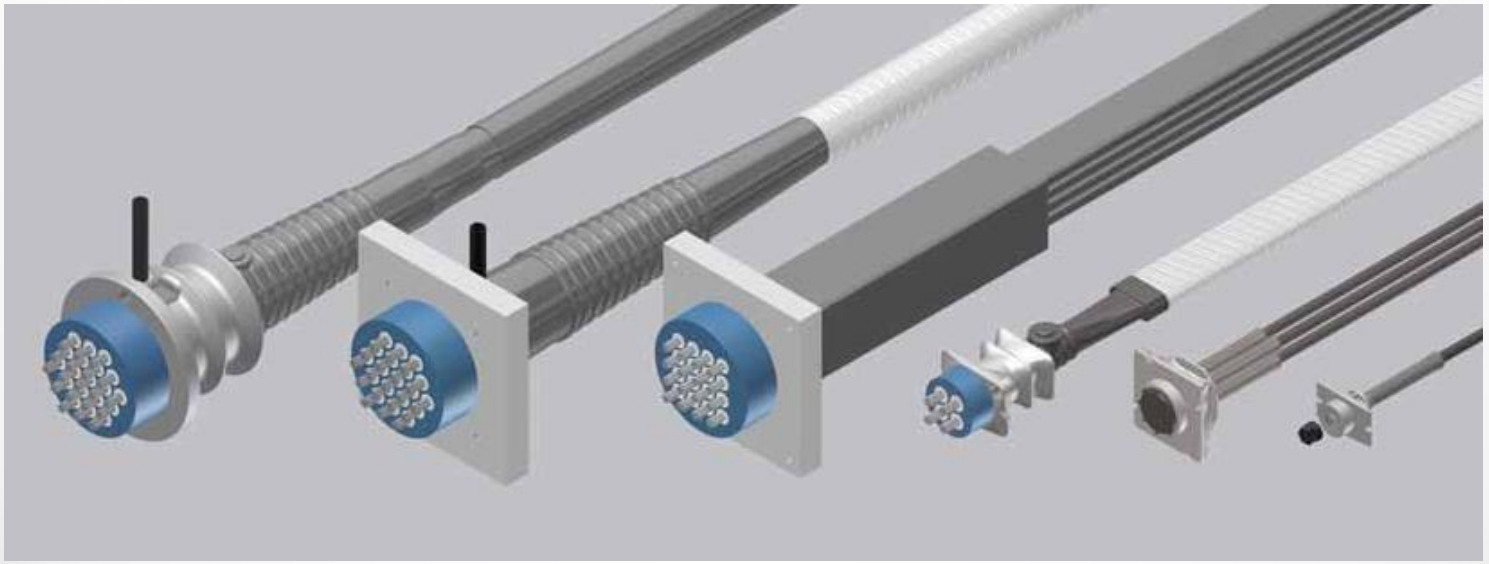
Evropska regulativa 305/2011 i sistemi za prethodno naprezanje

- **Uredba za građevinske proizvode / Regulation No. 305/2011 (Construction Products Regulation, or CPR) Evropskog Parlamenta i Evropskog Savjeta (of the European Parliament and of the European Council) je uredba od 9. marta 2011. kojom se utvrđuju usaglašeni uslovi za plasiranje građevinskih proizvoda i zamjenjuje Direktivu (89/106/EEC). Uloga Regulative je da pojasni okvir za stavljanje građevinskih proizvoda na tržište.**
- **U skladu sa Regulativom primjena sistema prethodnog naprezanja uslovljena je posjedovanjem ETA (European Technical Approval /European Technical Assessment) :**

BBR SISTEM

- **U okviru mreže BBR je razvijen modularni sistem za naknadno zatezanje BBR VT CONA CMX. Sastoji se od pet glavnih sistema:**
- **Ovaj sistem se primjenjuju u skladu sa Evropskim Tehničkim Odobrenjem (European Technical Approval).**

- **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



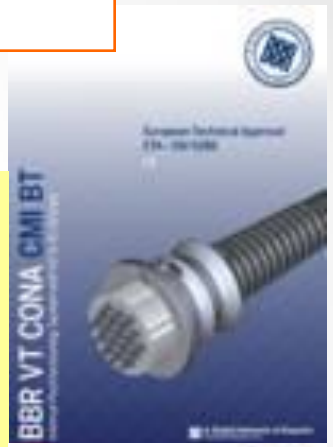
Sistem BBR VT CONA

http://www.bbrnetwork.com/downloads/approvals/etas.html

BBR VT CONA CMI - internal

BBR VT CONA CMI BT
Internal post-tensioning system

ETA-09/0286: 2 to 61 number strands for internal PT applications with **bearing trumplate** load transfer element.

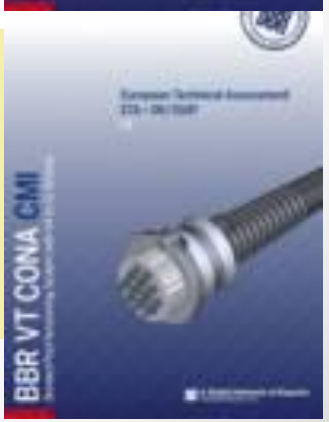


BBR VT CONA CMI SP
Internal post-tensioning system

ETA-09/0287: 1 to 61 number strands for internal PT applications with **square plate** load transfer element.

BBR VT CONA CMI –
Internal post-tensioning system

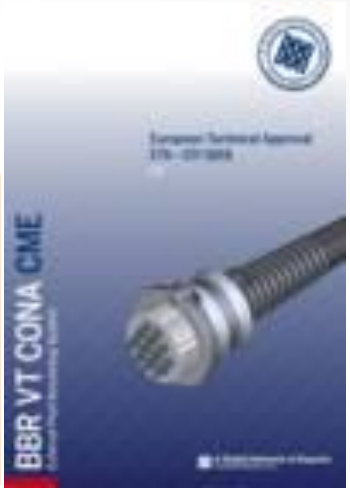
ETA-06/0147: Bonded Post tensioning System with 04 to 31 Strands



BBR VT CONA CME - external

BBR VT CONA CME
External post-tensioning system

ETA-07/0168: 4 to 31 strands for external PT applications.



BBR VT CONA CMF - flat

BBR VT CONA CMF
Internal flat post-tensioning system

ETA-12/0076: 2 to 4 number strands for internal flat PT applications.

BBR VT CONA CMM – monostrand

BBR VT CONA CMM
Monostrand post-tensioning system

ETA-06/0165: 1 to 4 number monostrands for internal PT applications.

BBR VT CONA CMM Single
Monostrand post-tensioning system

ETA-12/0282: single monostrands for internal PT applications.

BBR VT CONA CMB - band

BBR VT CONA CMB
Unbonded band post-tensioning system

ETA-10/0065: 1 to 16 number strands for external band PT applications.

Sistem BBR VT CONA CMI (internal)

- **U ovom sistemu koriste se užad od sedam žica.**
- **Koriste se užad od čelika karakteristične čvrstoće 1860 MPa, kao i 1770 MPa, nominalnog prečnika 15.3 mm, površine poprečnog presjeka 140 mm^2 i 15.7 mm površine poprečnog presjeka 150 mm^2.**
- **Kablovi se izrađuju upotrebom od 1 do 61 užeta od po sedam žica (2 do 61 za sistem sa livenom podložnom pločom).**
- **Karakteristična prekidna sila raspoloživih kablova je od 248 do 17019 kN.**

Kablovi sistema BBR sa ravnom podložnom pločom

BBR VT CONA CMI SP –
Internal Post-tensioning System with 01 to 61 Strands,

comprising the following components:

– Tendon

Internal tendons with 01 to 61 tensile elements.

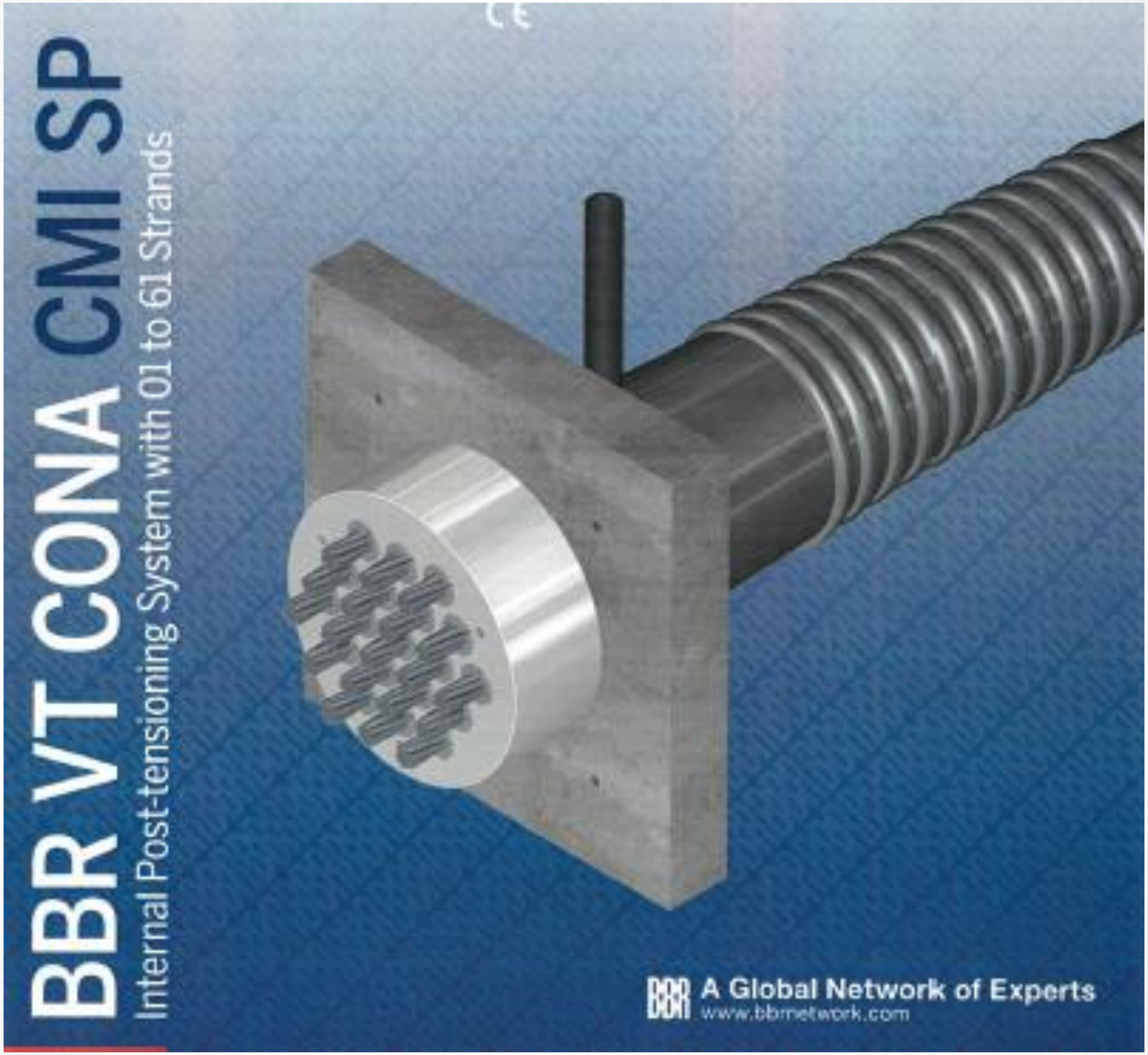
– Tensile element

7-wire prestressing steel strand with nominal diameter and maximum characteristic tensile strength as given in Table 1.

Table 1: Tensile elements

Nominal diameter	Nominal cross-sectional area	Maximum characteristic tensile strength
mm	mm^2	MPa
15.3	140	1 860
15.7	150	

NOTE 1 MPa = 1 N/mm^2


BBR VT CONA CMI SP
Internal Post-tensioning System with 01 to 61 Strands
A Global Network of Experts
www.bbrnetwork.com

Elementi sistema BBR sa livenom podložnom pločom (trumpet bearing)

BBR VT CONA CMI BT –
Internal Post-tensioning System with 02 to 61 Strands,

comprising the following components:

– Tendon

Internal tendons with 02 to 61 tensile elements.

– Tensile element

7-wire prestressing steel strand with nominal diameter and maximum characteristic tensile strength as given in Table 1.

Table 1: Tensile elements

Nominal diameter	Nominal cross-sectional area	Maximum characteristic tensile strength
mm	mm^2	MPa
15.3	140	1 860
15.7	150	

NOTE 1 MPa = 1 N/mm^2


BBR VT CONA CMI BT
Internal Post-tensioning System with 02 to 61 Strands
A Global Network of Experts
www.bbrnetwork.com

Elementi sistema BBR sa livenom podložnom pločom

- Anchorage and coupler

  Anchorage of the strands with ring wedges;

  End anchorage

    Fixed (passive) anchor or stressing (active) anchor as end anchorage for 02, 03, 04, 05, 06, 07, 08, 09, 12, 13, 15, 16, 19, 22, 24, 25, 27, 31, 37, 42, 43, 48, 55 and 61 strands;

  Fixed or stressing coupler

    Single plane coupler for 02, 03, 04, 05, 06, 07, 08, 09, 12, 13, 15, 16, 19, 22, 24, 25, 27, and 31 strands;

    Sleeve coupler for 02, 03, 04, 05, 06, 07, 08, 09, 12, 13, 15, 16, 19, 22, 24, 25, 27, 31, 37, 42, 43, 48, 55 and 61 strands;

  Movable coupler

    Single plane coupler for 02, 03, 04, 05, 06, 07, 08, 09, 12, 13, 15, 16, 19, 22, 24, 25, 27, and 31 strands;

    Sleeve coupler for 02, 03, 04, 05, 06, 07, 08, 09, 12, 13, 15, 16, 19, 22, 24, 25, 27, 31, 37, 42, 43, 48, 55 and 61 strands;

- Bearing trumplate for 02, 03, 04, 05, 06, 07, 08, 09, 12, 13, 15, 16, 19, 22, 24, 25, 27, 31, 37, 42, 43, 48, 55 and 61 strands;

- Helix and additional reinforcement in the region of the anchorage;
- Corrosion protection for tensile elements, couplers and anchorages.

CONA CMI BT n06-140

Number of strands	Nominal cross-sectional area of prestressing steel	Nominal mass of prestressing steel	Characteristic value of maximum force of tendon	
			f_{pk} = 1 770 MPa	f_{pk} = 1 860 MPa
n	A_p	M	F_{pk}	F_{pk}
—	mm^2	kg/m	kN	kN
02	280	2.2	496	520
03	420	3.3	744	780
04	560	4.4	992	1 040
05	700	5.5	1 240	1 300
06	840	6.6	1 488	1 560
07	980	7.7	1 736	1 820
08	1 120	8.7	1 984	2 080
09	1 260	9.8	2 232	2 340
12	1 680	13.1	2 976	3 120
13	1 820	14.2	3 224	3 380
15	2 100	16.4	3 720	3 900
16	2 240	17.5	3 968	4 160
19	2 660	20.8	4 712	4 940
22	3 080	24.0	5 456	5 720
24	3 360	26.2	5 952	6 240
25	3 500	27.3	6 200	6 500
27	3 780	29.5	6 696	7 020
31	4 340	33.9	7 688	8 060
37	5 180	40.4	9 176	9 620
42	5 880	45.9	10 416	10 920
43	6 020	47.0	10 664	11 180
48	6 720	52.5	11 904	12 480
55	7 700	60.1	13 640	14 300
61	8 540	66.7	15 128	15 860

Kablovi sistema

BBR VT Cona CMI BT

CONA CMI BT n06-150

Number of strands	Nominal cross-sectional area of prestressing steel	Nominal mass of prestressing steel	Characteristic value of maximum force of tendon	
			f_{pk} = 1 770 MPa	f_{pk} = 1 860 MPa
n	A_p	M	F_{pk}	F_{pk}
—	mm^2	kg/m	kN	kN
02	300	2.3	532	558
03	450	3.5	798	837
04	600	4.7	1 064	1 116
05	750	5.9	1 330	1 395
06	900	7.0	1 596	1 674
07	1 050	8.2	1 862	1 953
08	1 200	9.4	2 128	2 232
09	1 350	10.5	2 394	2 511
12	1 800	14.1	3 192	3 348
13	1 950	15.2	3 458	3 627
15	2 250	17.6	3 990	4 185
16	2 400	18.8	4 256	4 464
19	2 850	22.3	5 054	5 301
22	3 300	25.8	5 852	6 138
24	3 600	28.1	6 384	6 696
25	3 750	29.3	6 650	6 975
27	4 050	31.6	7 182	7 533
31	4 650	36.3	8 246	8 649
37	5 550	43.4	9 842	10 323
42	6 300	49.2	11 172	11 718
43	6 450	50.4	11 438	11 997
48	7 200	56.3	12 768	13 392
55	8 250	64.5	14 630	15 345
61	9 150	71.5	16 226	17 019

Kablovi sistema BBR

BBR VT Cona CMI BT

Komponente kablova sa ankernim dijelom za naknadno zatezanje

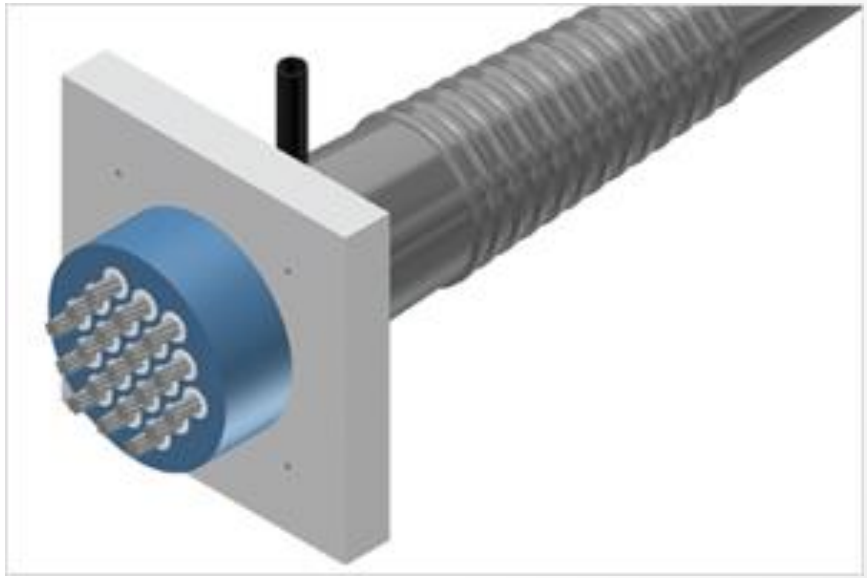
BBR VT CONA CMI

internal post tensioning system

BBR VT CONA CME external post-tensioning system

The European approved CONA® CME post-tensioning system is the ultimate multi-strand technology for all types of externally post-tensioned applications. The standard tendon sizes range from 1 to 73 strands. CONA CME can be applied for the prestressing of bridges, precast segmental construction and repair and strengthening works of all kind of structures.

CONA CME BT



CONA CME SP

VSL Sistem

Internal tendons – the most commonly-used solution

The VSL systems are based on the method of post-tensioning. Most applications of the multi-strand system are internal and cement grouted, providing bond to the structure. Such tendons are extensively used in bridges and transportation structures as well as being applied successfully in building construction.


Shenzhen Western Corridor,
Hong Kong - 2004

1 - STRAND

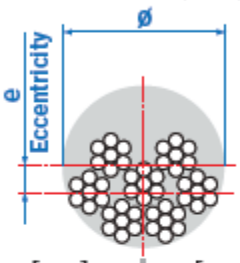
1.1 - STRAND PROPERTIES 13mm (0.5")

Strand type			prEN 10138 – 3 (2006) Y1860S7		ASTM A 416-06 Grade 270
Nominal diameter	d	(mm)	12.5	12.9	12.7
Nominal cross section	A_p	(mm^2)	93	100	98.7
Nominal mass	M	(kg/m)	0.726	0.781	0.775
Nominal yield strength	$f_{p0,1k}$	(MPa)	1634[1]	1640[1]	1675[2]
Nominal tensile strength	f_{pk}	(MPa)	1860	1860	1860
Specif./min. breaking load	F_{pk}	(kN)	173	186	183.7
Young's modulus		(GPa)	approx. 195		
Relaxation[3] after 1000 h at 20°C and 0.7 x F_{pk}		(%)	max. 2.5		

1) Characteristic value measured at 0.1% permanent extension
2) Minimum load at 1% extension for low-relaxation strand
3) Valid for relaxation class acc. to prEN 10138-3 or low-relaxation grade acc. to ASTM A 416-06

1.2 - TENDON PROPERTIES 13mm (0.5")

Unit	Strands numbers	Steel area			Breaking load			Corrugated steel duct[3] (recommended)		Corrugated plastic duct VSL PT-PLUS®	
		A_p acc. to prEN		ASTM	Y1860S7 (prEN)		Grade 270 (ASTM)	Øi / Øe	e	Øi / Øe	e
		d=12.5 mm A_p=93 mm²	d=12.9 mm A_p=100 mm²	d=12.7 mm A_p=100 mm²	d=12.5 mm A_p=93 mm²	d=12.9 mm A_p=100 mm²	d=12.7 mm A_p=98.7 mm²				
		[mm²]	[mm²]	[mm²]	[kN]	[kN]	[kN]	[mm]	[mm]	[mm]	[mm]
5-1	1	93	100	98.7	173	186	183.7	20/25	3	22/25	6
5-2	2	186	200	197	346	372	367	35/40	8	76/25[2]	-
5-3	3	279	300	296	519	558	551	35/40	6	76/25[2]	-
5-4	4	372	400	395	692	744	735	40/45[1]	7	76/25[2]	-
5-7	5	465	500	494	865	930	919	45/50	8	58/63	14
|	6	558	600	592	1038	1116	1102	45/50	6	58/63	12
5-7	7	651	700	691	1211	1302	1286	50/57	7	58/63	11
5-12	8	744	800	790	1384	1488	1470	55/62	9	58/63	10
|	9	837	900	888	1557	1674	1653	55/62	8	58/63	9
|	10	930	1000	987	1730	1860	1837	60/67	10	58/63	9
|	11	1023	1100	1086	1903	2046	2021	60/67	9	58/63	8
5-12	12	1116	1200	1184	2076	2232	2204	60/67	8	58/63	7
5-15	13	1209	1300	1283	2249	2418	2388	65/72	9	76/81	14
|	14	1302	1400	1382	2422	2604	2572	65/72	8	76/81	13
5-15	15	1395	1500	1481	2595	2790	2756	70/77	9	76/81	12
5-19	16	1488	1600	1579	2768	2976	2939	70/77	9	76/81	12
|	17	1581	1700	1678	2941	3162	3123	75/82	11	76/81	11
|	18	1674	1800	1777	3114	3348	3307	75/82	10	76/81	10
5-19	19	1767	1900	1875	3287	3534	3490	75/82	9	76/81	9
5-22	20	1860	2000	1974	3460	3720	3674	80/87	10	100/106	20



Prikazan je dio tabele. Najveći kablovi sadrže 55 užadi i zatežu se max silom pri prekidu 10230 kN.

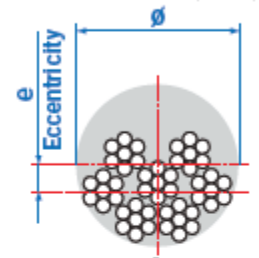
1.3 - STRAND PROPERTIES 15mm (0.6")

Strand type			prEN 10138 – 3 (2006) Y1860S7		ASTM A 416-06 Grade 270
Nominal diameter	d	(mm)	15.3	15.7	15.24
Nominal cross section	A_p	(mm^2)	140	150	140
Nominal mass	M	(kg/m)	1.093	1.172	1.102
Nominal yield strength	$f_{p0,1k}$	(MPa)	1636[1]	1640[1]	1676[2]
Nominal tensile strength	f_{pk}	(MPa)	1860	1860	1860
Specif./min. breaking load	F_{pk}	(kN)	260	279	260.7
Young's modulus		(GPa)	approx. 195		
Relaxation[3] after 1000 h at 20°C and 0.7 x F_{pk}		(%)	max. 2.5		

1) Characteristic value measured at 0.1% permanent extension
2) Minimum load at 1% extension for low-relaxation strand
3) Valid for relaxation class acc. to prEN 10138-3 or low-relaxation grade acc. to ASTM A 416-06

1.4 - TENDON PROPERTIES 15mm (0.6")

Unit	Strands numbers	Steel area			Breaking load			Corrugated steel duct[3] (recommended)		Corrugated plastic duct VSL PT-PLUS®	
		Ap acc. to prEN		ASTM	Y1860S7 (prEN)		Grade 270 (ASTM)	Øi / Øe	e	Øi / Øe	e
		d=15.3 mm Ap=140 mm²	d=15.7 mm Ap=150 mm²	d=15.24 mm Ap=140 mm²	d=15.3 mm Ap=140 mm²	d=15.7 mm Ap=150 mm²	d=15.24 mm Ap=140 mm²				
		[mm²]	[mm²]	[mm²]	[kN]	[kN]	[kN]	[mm]	[mm]	[mm]	[mm]
6-1	1	140	150	140	260	279	260.7	25/30	5	22/25	4
6-2	2	280	300	280	520	558	521	40/45	9	76/25[2]	-
6-3	3	420	450	420	780	837	782	40/45	6	76/25[2]	-
6-4	4	560	600	560	1040	1116	1043	45/50[1]	7	76/25[2]	-
6-7	5	700	750	700	1300	1395	1304	50/57	8	58/63	13
|	6	840	900	840	1560	1674	1564	55/62	9	58/63	11
6-7	7	980	1050	980	1820	1953	1825	55/62	7	58/63	9
6-12	8	1120	1200	1120	2080	2232	2086	65/72	11	76/81	18
|	9	1260	1350	1260	2340	2511	2346	65/72	9	76/81	16
|	10	1400	1500	1400	2600	2790	2607	70/77	11	76/81	15
|	11	1540	1650	1540	2860	3069	2868	70/77	9	76/81	13
6-12	12	1680	1800	1680	3120	3348	3128	75/82	11	76/81	12
6-15	13	1820	1950	1820	3380	3627	3389	80/87	13	100/106	25
|	14	1960	2100	1960	3640	3906	3650	80/87	11	100/106	24
6-15	15	2100	2250	2100	3900	4185	3911	80/87	10	100/106	23
6-19	16	2240	2400	2240	4160	4464	4171	85/92	12	100/106	22
|	17	2380	2550	2380	4420	4743	4432	85/92	11	100/106	20
|	18	2520	2700	2520	4680	5022	4693	90/97	13	100/106	19
6-19	19	2660	2850	2660	4940	5301	4953	90/97	12	100/106	18
6-22	20	2800	3000	2800	5200	5580	5214	100/107	17	100/106	17



Samo dio tabele je prikazan. Najveći kablovi su sa 55 užadi i silom 15345 kN.

VSLab® S system

This European Technical Approval (ETA) applies to the following post-tensioning kit: VSLab® S system with 2, 3, 4 and 5 strands

Uslov iz Standarda EN 10138-3

$P_{max} = \min \{k_1.A_p.f_{pk}; k_2.A_p.f_{p0.1k}\}$, with $k_1 = 0.8$, $k_2 = 0.9$, $f_{pk} = 1\,860$ N/mm$_2$, $f_{p0.1k} = 0.88\ f_{pk}$

Qty. of strands	Strand ∅ 15.3 $f_{pk} = 1\,860$ N/mm^2 $F_{pk} = 260$ kN			$F_{p0.1k} = 229$ kN		Strand ∅ 15.7 $f_{pk} = 1\,860$ N/mm^2 $F_{pk} = 279$ kN			$F_{p0.1k} = 246$ kN	
	A_p	$A_p.f_{pk}$	0.8 $A_p.f_{pk}$	$A_p.f_{p0.1k}$	0.9 $A_p.f_{p0.1k}$	A_p	$A_p.f_{pk}$	0.8 $A_p.f_{pk}$	$A_p.f_{p0.1k}$	0.9 $A_p.f_{p0.1k}$
	mm^2	kN	kN	kN	kN	mm^2	kN	kN	kN	kN
2	280	521	417	459	413	300	558	446	492	443
3	420	781	625	688	619	450	837	670	738	664
4	560	1042	833	917	826	600	1116	893	984	886
5	700	1302	1042	1147	1032	750	1395	1116	1230	1107

Note : prestressing force applied to structure must be in accordance with national regulations.

Qty. of strands	Strand ∅ 15.7 f_{pk} = 1 770 N/mm2 F_{pk} = 265 kN			$F_{p0.1k}$ = 236 kN	
	A_p	$A_p.f_{pk}$	0.8 $A_p.f_{pk}$	$A_p.f_{p0.1k}$	0.9 $A_p.f_{p0.1k}$
	mm^2	kN	kN	kN	kN
2	300	530	424	472	425
3	450	795	636	708	637
4	600	1060	848	944	850
5	750	1325	1060	1180	1062
Note : prestressing force applied to structure must be in accordance with national regulations					

DYWIDAG sistem

Podaci o užadima

▶ Technical Data

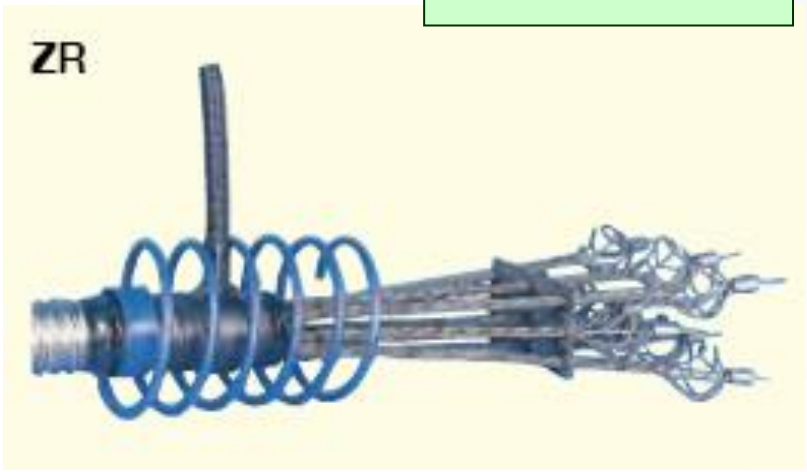
type code/specification		13 mm (0.5") ASTM A 416 Grade 270	13 mm (0.5") prEN 10138 BS 5896	15 mm (0.6") ASTM A 416 Grade 250	15 mm (0.6") prEN 10138 BS 5896	15 mm (0.6") ASTM A 416 Grade 270	15 mm (0.6") prEN 10138 BS 5896
yield strength $f_{p0.1k}$	N/mm²	1,670[1]	1,640[2]	1,550[1]	1,560[2]	1,670[1]	1,640[2]
ultimate strength f_{pk}	N/mm²	1,860	1,860	1,725	1,770	1,860	1,860
nom. diameter	mm	12.70	12.90	15.20	15.70	15.24	15.70
cross-sectional area	mm²	98.71	100.00	139.40	150.00	140.00	150.00
weight	kg/m	0.775	0.785	1.094	1.180	1.102	1.18
ultimate load	kN	183.7	186.0	240.2	265.5	260.7	279.0
modulus of elasticity	N/mm²	~195,000					
relaxation[3] after 1,000 h at 0.7 x ultimate strength f_{pk}	%	max. 2.5					

[1] yield measured at 1% effective elongation
[2] yield measured at 0.1% residual elongation
[3] applicable for relaxation class 2 according to Eurocode prEN 10138/BS 5896: or low relaxation complying with ASTM A 416, respectively.

DYWIDAG sistem

Aktivna kotva

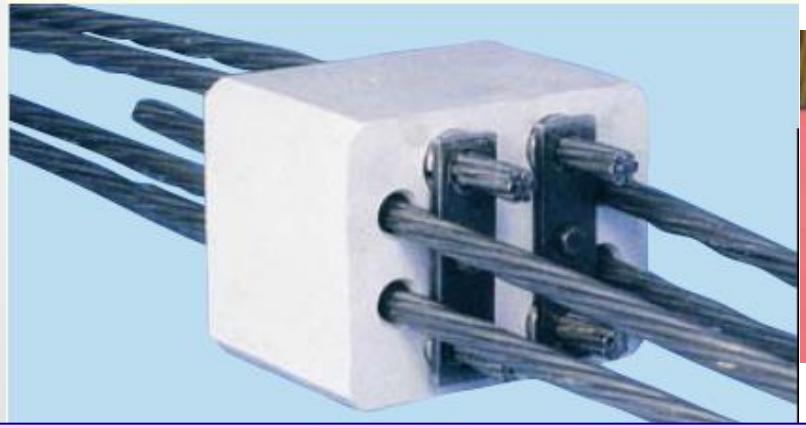
Fiksna kotva



Kotva za sidrenje kablova u ploči

DYWIDAG sistem

Prethodno naprezanje ploča



Element za povezivanje užadi kod kružnog prethodnog naprezanja (rezervoara, cijevi velikog prečnika, kupola)

DYWIDAG sistem

Tehnički podaci o šipkama

Technical data

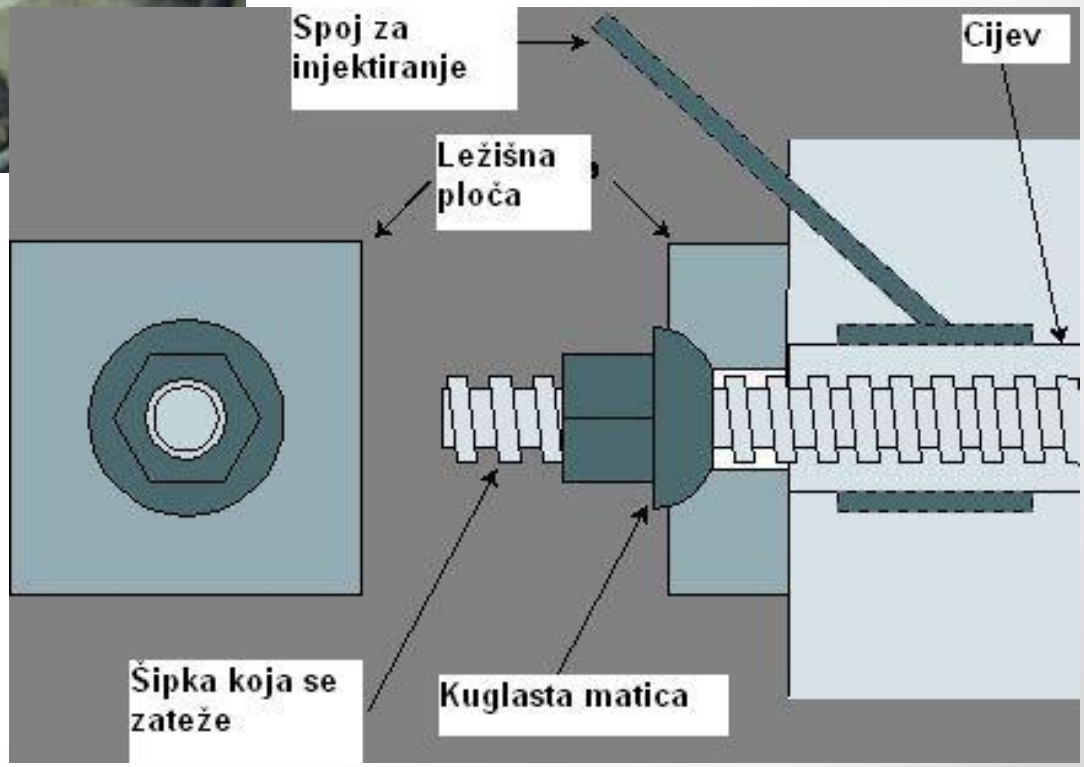
			THREADBAR®					Plain bar	
Designation	–	–	26 WR	32 WR	36 WR	40 WR	47 WR	32 WS	36 WS
Nominal diameter	d_s	mm	26.5	32	36	40	47	32	36
Cross section area	S_n	mm²	552	804	1018	1257	1735	804	1018
Nominal mass per metre	M	kg/m	4.46[1)]	6.53[1)]	8.27[1)]	10.21[1)]	14.10[1)]	6.31	7.99
Pitch	c	mm	13	16	18	20	21	3.0	3.0
Characteristic breaking load	F_m	kN	580	845	1070	1320	1820	845	1070
Max. initial stressing force $P_{m0,max} = S_n \times 0.8 \times f_{p,k}$		kN	464	676	856	1056	1456	676	856
Max. overstressing force $P_{0,max} = S_n \times 0.95 \times f_{p0,1k}$		kN	499	722	912	1130	1567	722	912

1) The nominal mass per metre includes 3.5% not load bearing portion of ribs.

DYWIDAG sistem

Zatezanje

Sidrenje



DYWIDAG sistem

Uređaj za potiskivanje kablova pri uvlačenju u zaštitne cijevi.

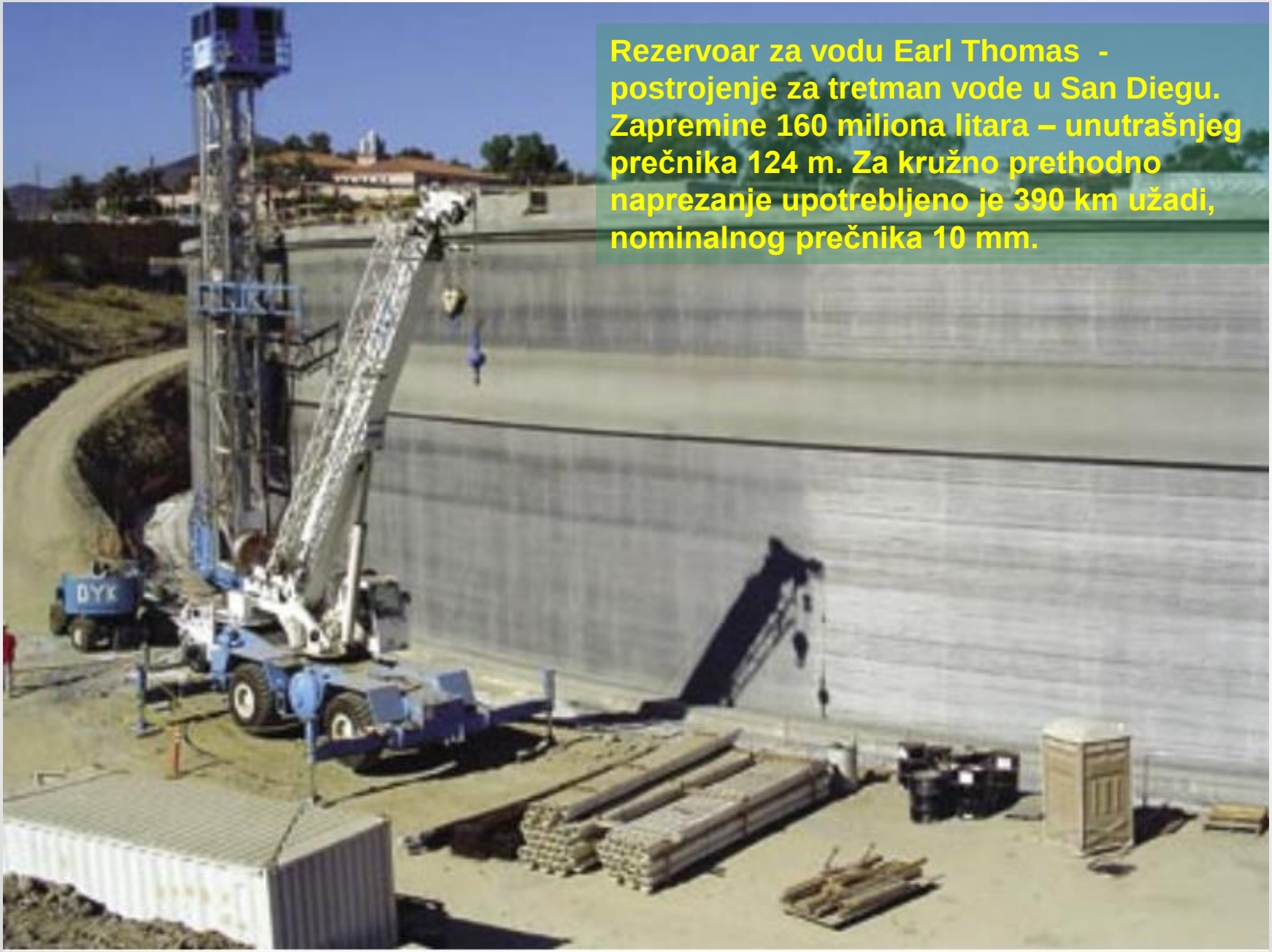
Strand Pusher

Miješalica sa pumpom za injektiranje

Hidraulična presa za zatezanje šipki

Primjena prethodnog naprezanja

Rezervoari



Rezervoar za vodu Earl Thomas - postrojenje za tretman vode u San Diegu. Zapremine 160 miliona litara – unutrašnjeg prečnika 124 m. Za kružno prethodno naprezanje upotrebljeno je 390 km užadi, nominalnog prečnika 10 mm.

Silosi

Silos za cement u Kataru

Prethodno naprezanje silosa - spolja

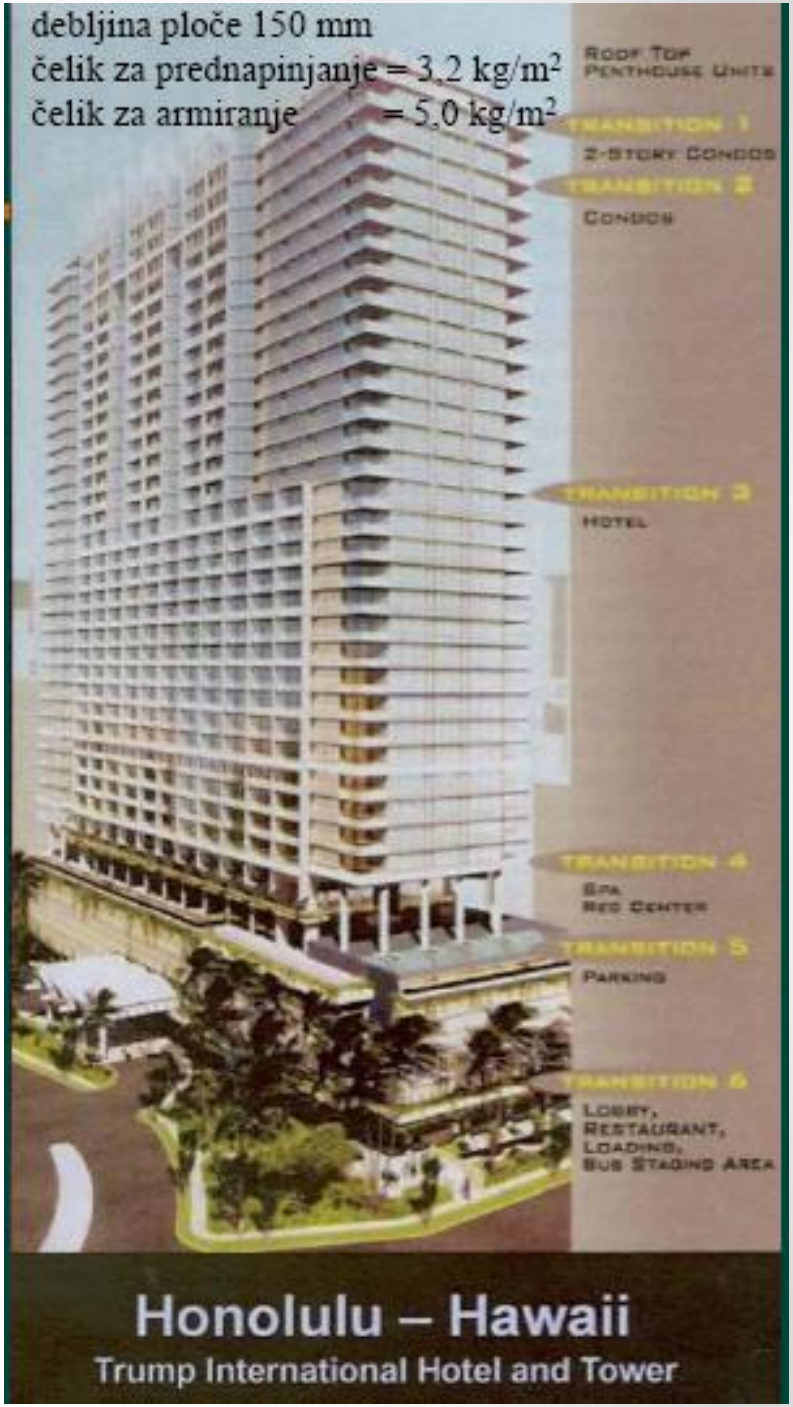
Rasponske konstrukcije mostova

A10 Arruda dos Vinhos, Portugal

Uhlavu Bridge, Pilsen, Czech Republic

Visoke zgrade

Post-Tower, Bonn, Germany



Zgrada Nacionalne banke u Abu Dabiju

Zgrada Evropskog Parlamenta u Strazburu

Prethodnim naprezanjem je redukovana debljina tavanica, obezbijeđena stabilnost i seizmička otpornost i optimizovan slobodan raspon.

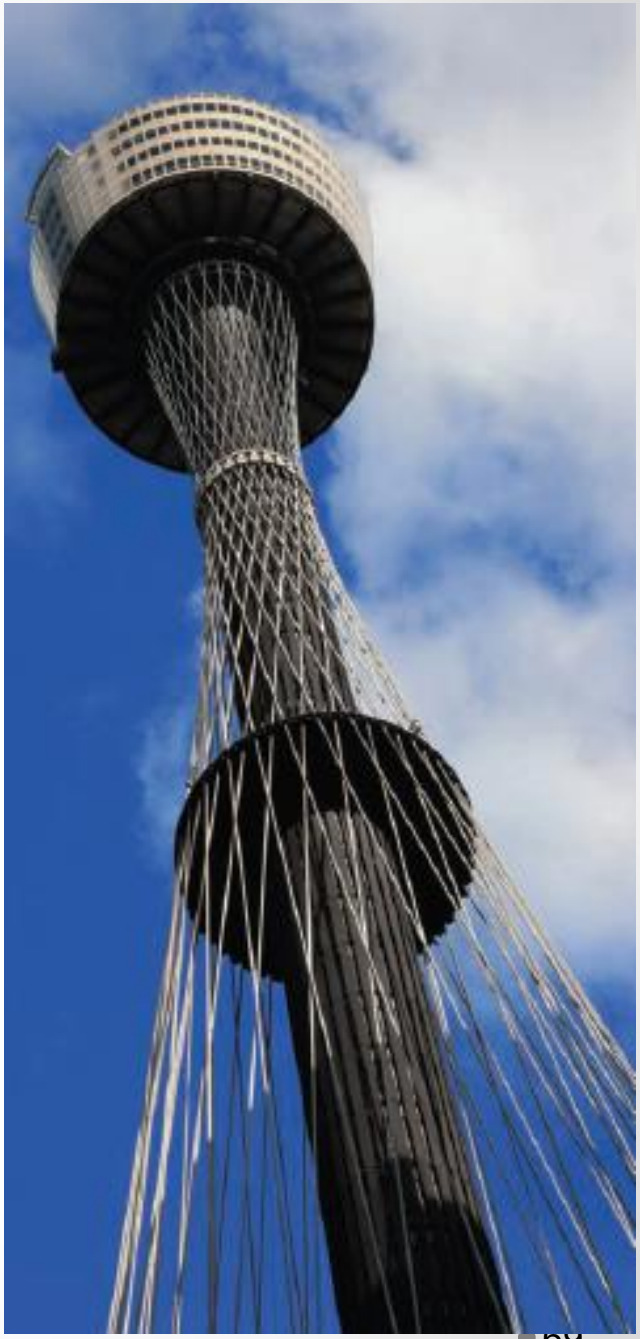
Prestižna poslovna zgrada Esso Glen u centru Londona gdje je izrađeno 50000m^2 prethodno napregnutih tavanica.

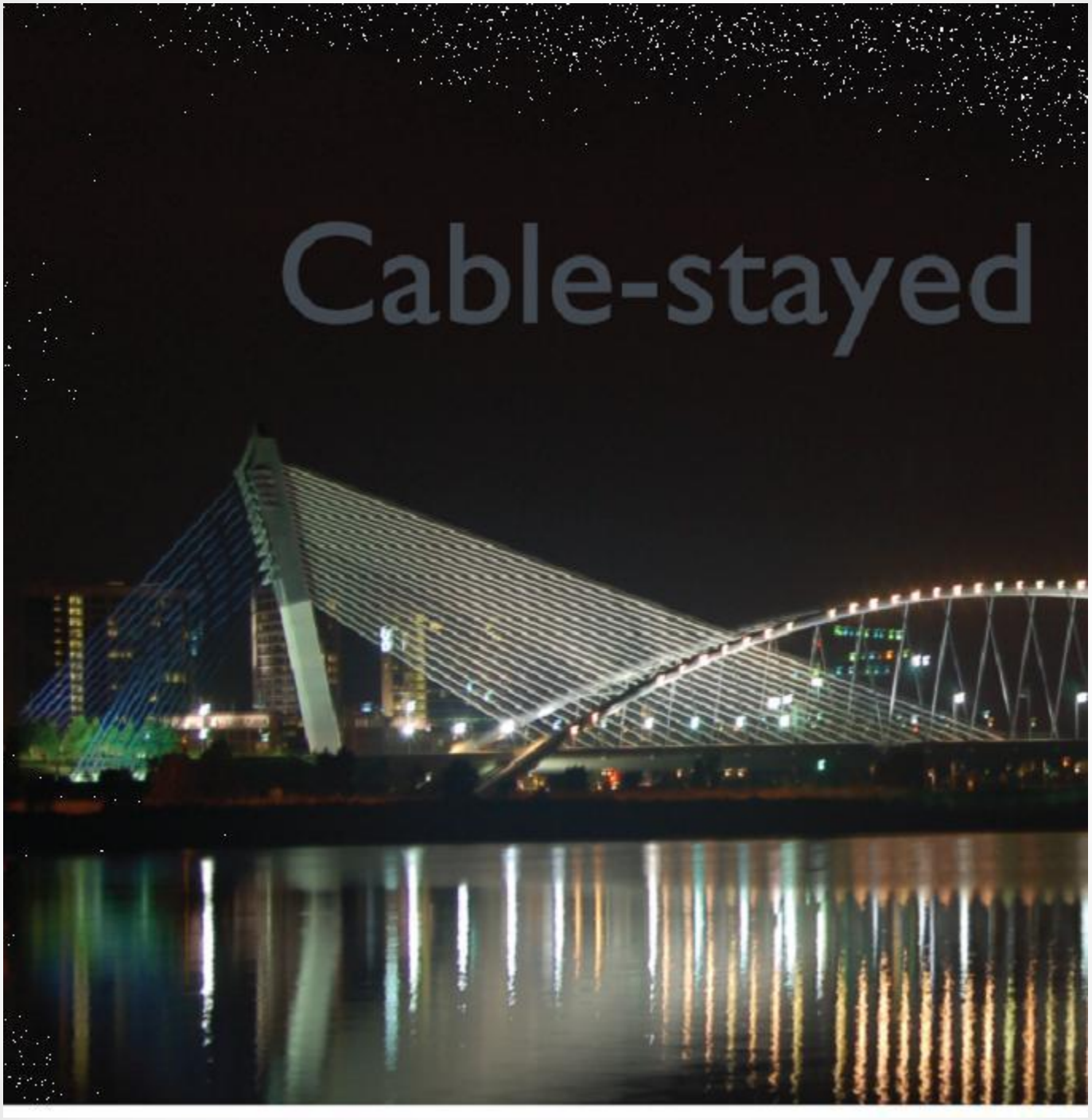
72000m^2 prethodno napregnutih tavanica je izrađeno pri gradnji fabrike za tretman vode (Vilvoorde, Belgium)

Temelji i hidrotehničke građevine

Cable-stayed sistem se primjenjuje za:

- ✓Viseće mostove (cable-stayed)
- ✓Lučne mostove
- ✓Krovove (stadioni, avionski hangari)
- ✓Tornjeve (telekomunikacione i sl.)




Cable-stayed

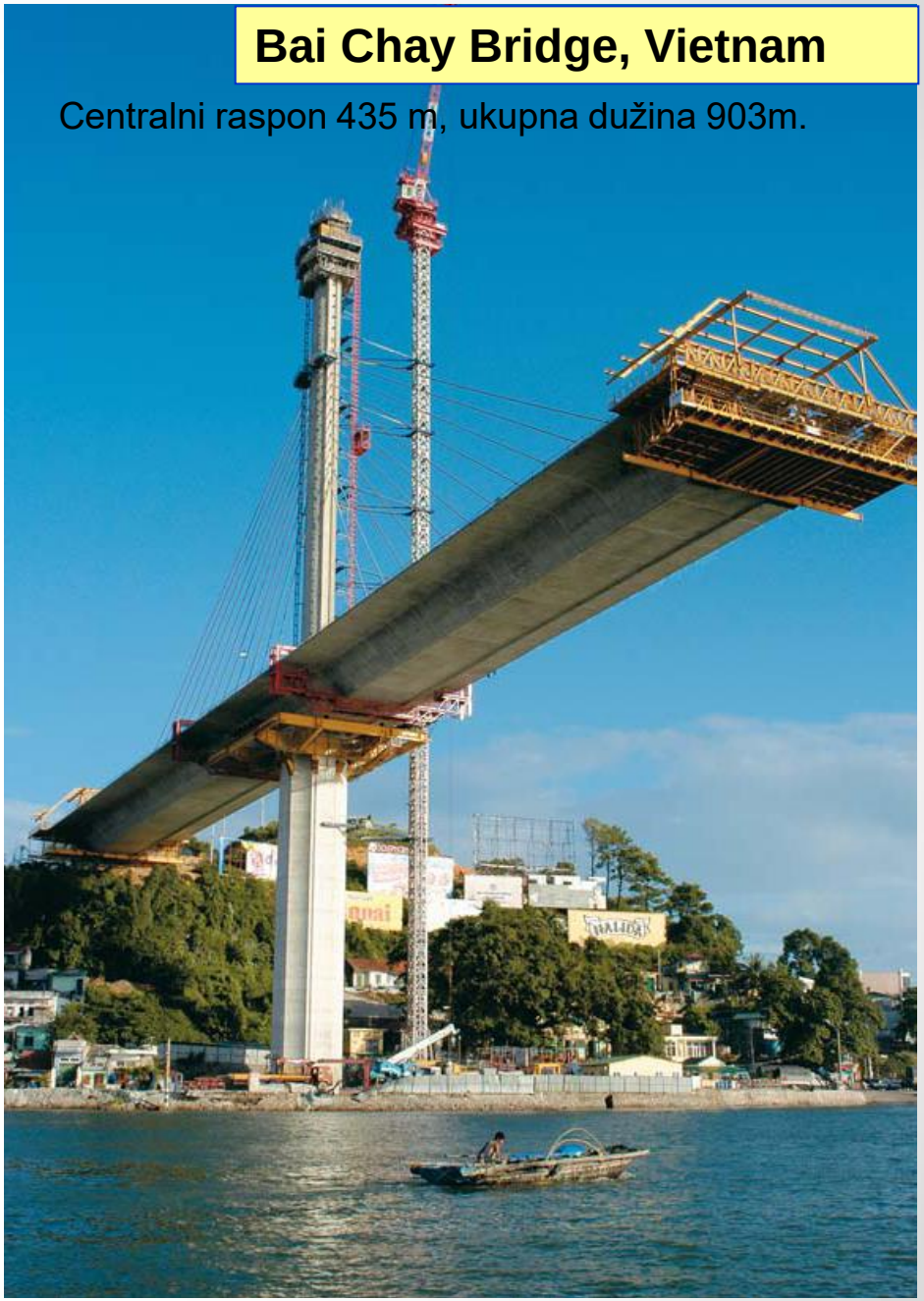
On the Moraca River

Montenegro. After commencing in May 2005, the installation of the stay cables on the Millennium Bridge, near Podgorica, was completed at the beginning of the summer and the structure was inaugurated on 13 July last. Freyssinet supplied the stay cables (300 t) for the structure, which crosses the Moraca River with a span of 173 m and supervised their installation by the general contractor as part of its role as technical support provider, 1).

[1)]Soils & Structures, Second half of 2005

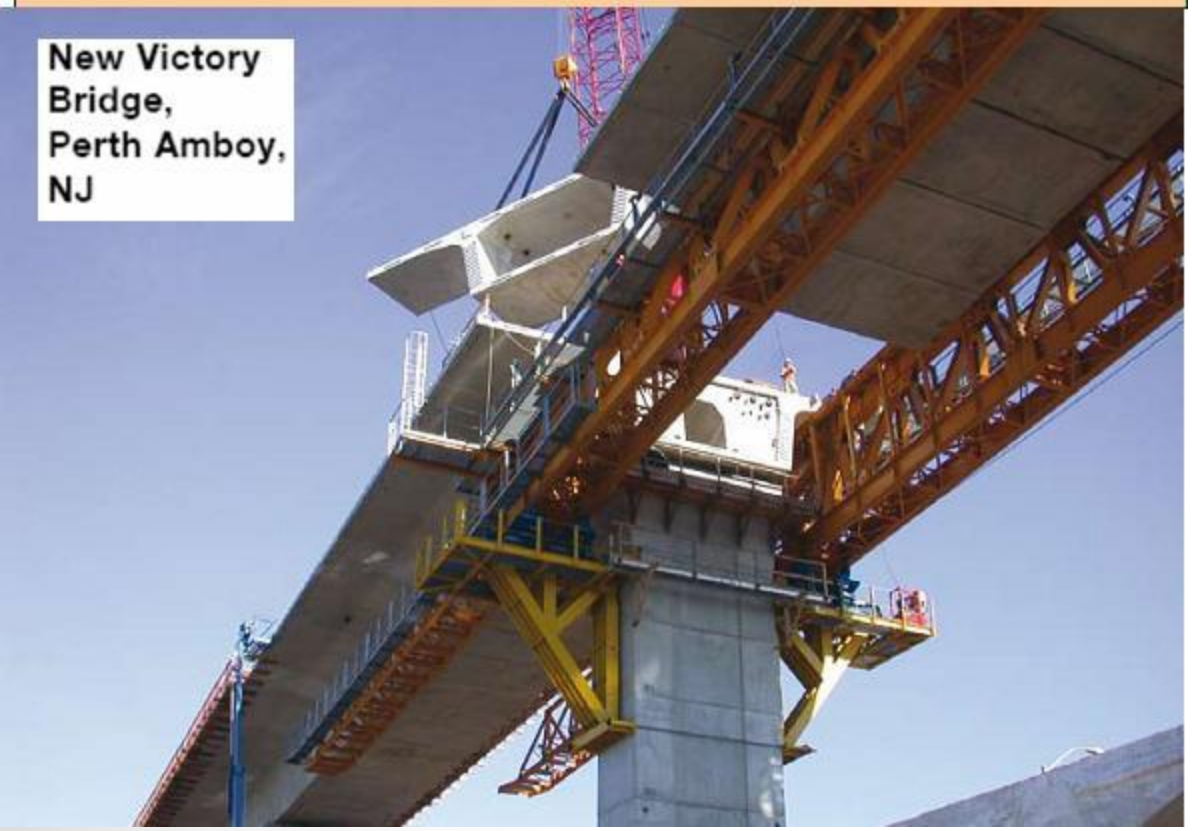
Bai Chay Bridge, Vietnam

Centralni raspon 435 m, ukupna dužina 903m.

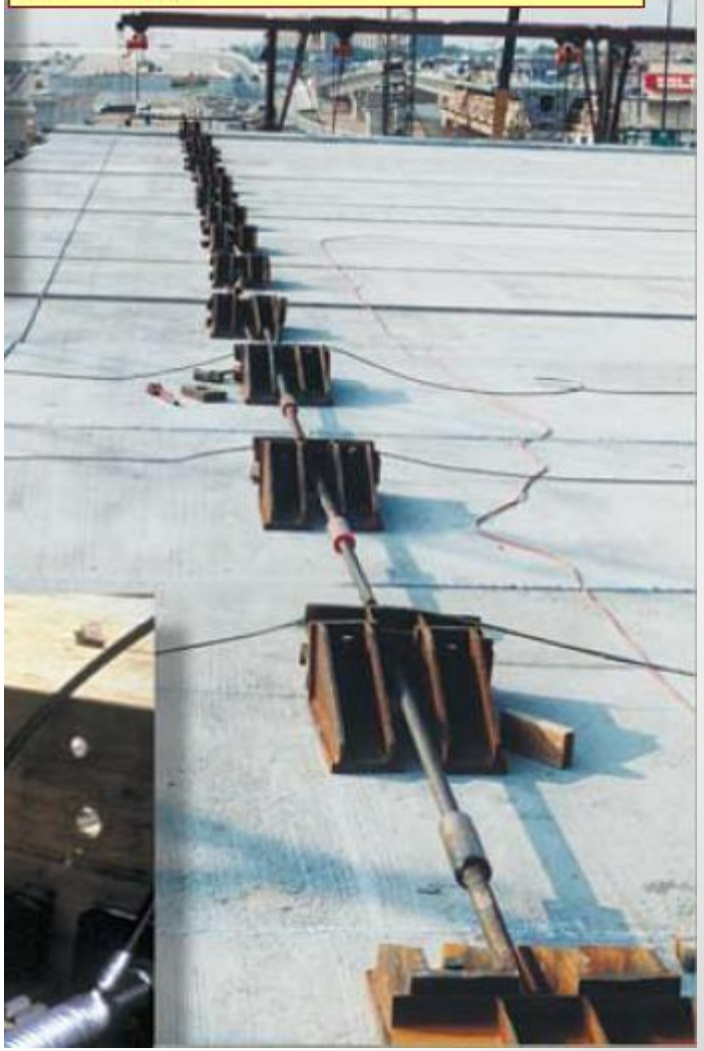


Segmentna gradnja

Most u izgradnji, od prefabrikovanih segmenata, koji se povezuju prethodnim naprezanjem



Privremeno postavljene šipke pri segmentnoj gradnji



Most na autoputu u Maroku

Građen je od segmenata livenih na licu mjesta uz primjenu prethodnog naprezanja.

Most na autoputu u Mađarskoj

Prethodno napregnut kablovima, sa 17 raspona: 60+95+13x120+95+60; građen metodom konzolne gradnje.

Prefabrikovani prethodno napregnuti elementi

Šuplje ploče

Željeznički pragovi