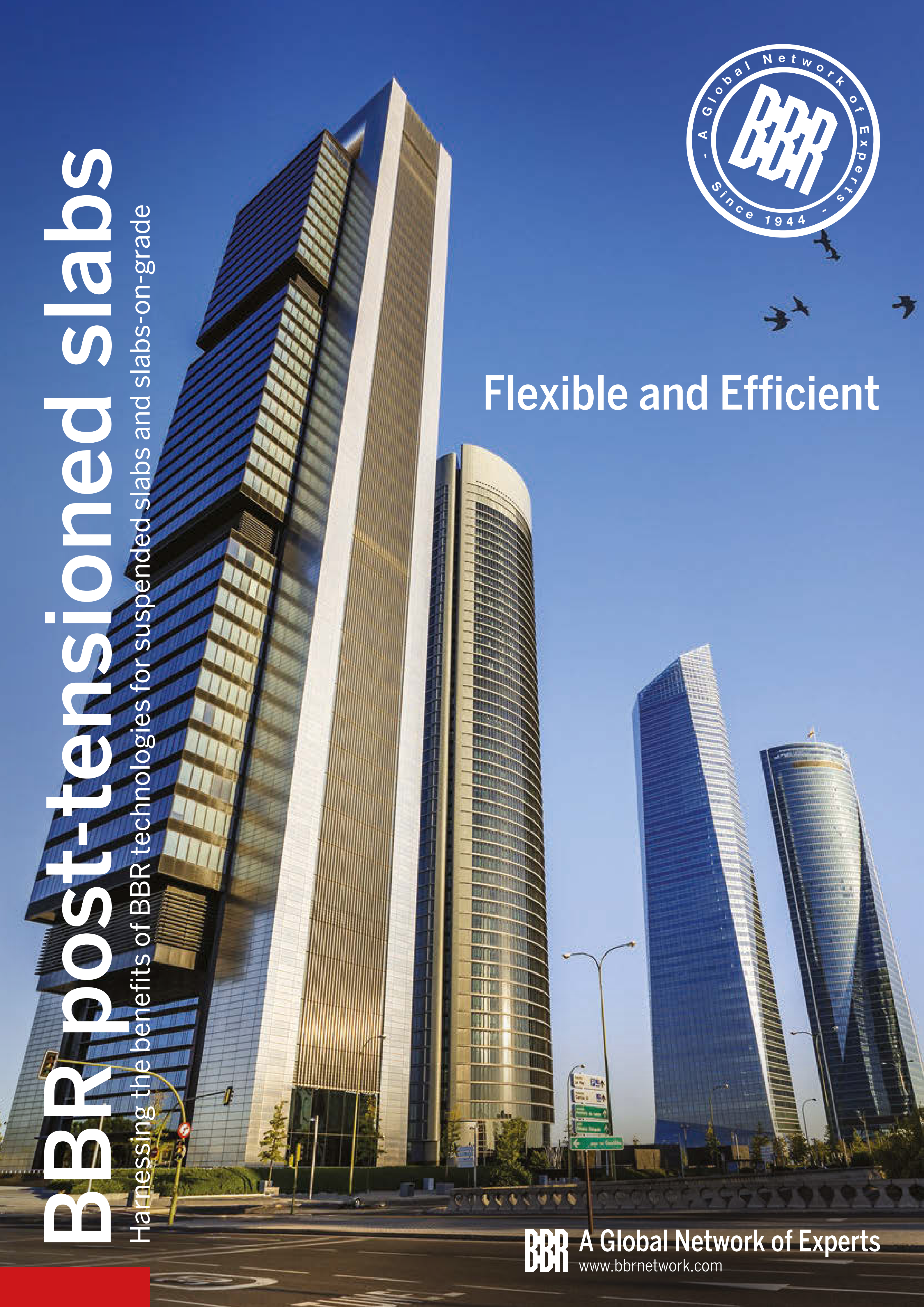
BBR post-tensioned slabs

Harnessing the benefits of BBR technologies for suspended slabs and slabs-on-grade

A Global Network of Experts - Since 1944 -



Flexible and Efficient

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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).

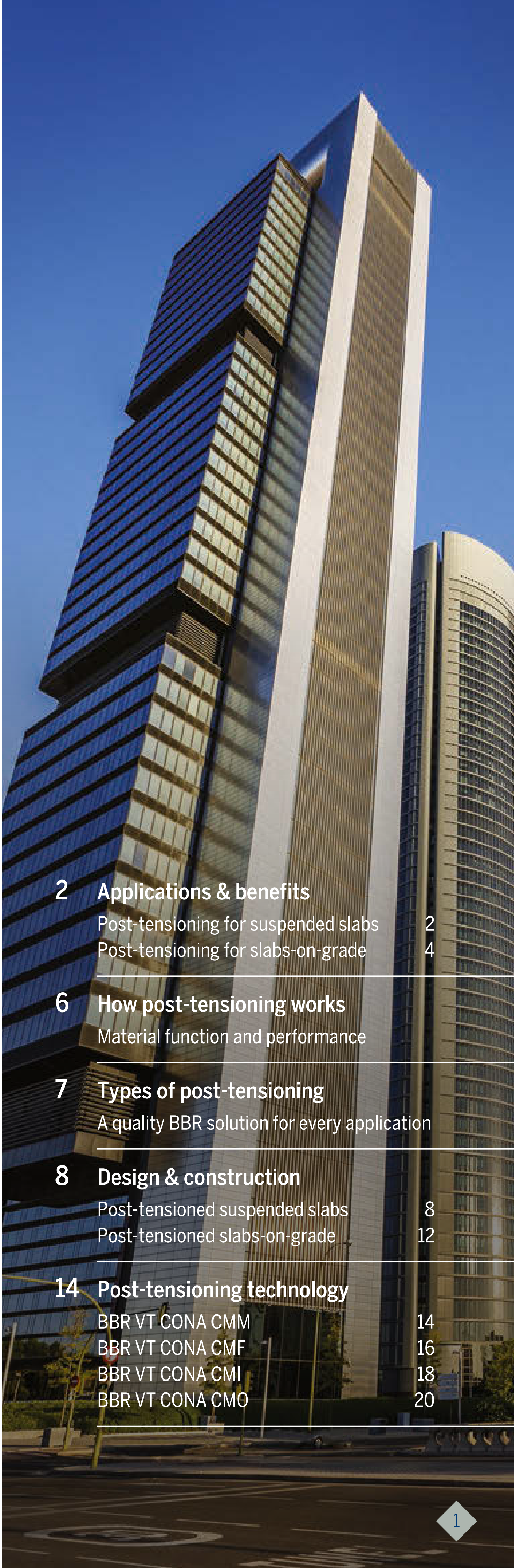
Everyone's a winner!

An architect's dream, a delight for developers, a great tool for builders and kind on the environment – post-tensioning in suspended flat slabs or slabs-on-grade allows almost any shape of structure to be constructed, while reducing environmental impacts, construction time, materials and costs.

Over the next few pages, you will learn more about the benefits of post-tensioning and amongst other things it can offer:

- greater flexibility of design and floor space usage
- faster construction program
- increased rentable floor area
- lower construction material costs
- reduced maintenance costs
- potential for reducing the overall height of a building or adding additional floor levels within the same overall building envelope
- improved whole life costs & durability
- reduced environmental impact.

BBR's experience with post-tensioned slabs dates back to the early seventies. Since then the different systems have evolved and have been optimized to suit the ever-increasing demand for more efficient and economical construction methods. Our latest post-tensioning technologies allow more freedom than ever before for architectural and design creativity. The following pages are our invitation to you to join us on a journey and discover how, together, we can maximize the value of your next building project.



Applications & benefits

Post-tensioning for suspended slabs

Post-tensioned concrete structures have achieved widespread popularity in recent years owing to their inherent advantages which allow designers and architects more freedom and flexibility across a wide range of different structures.

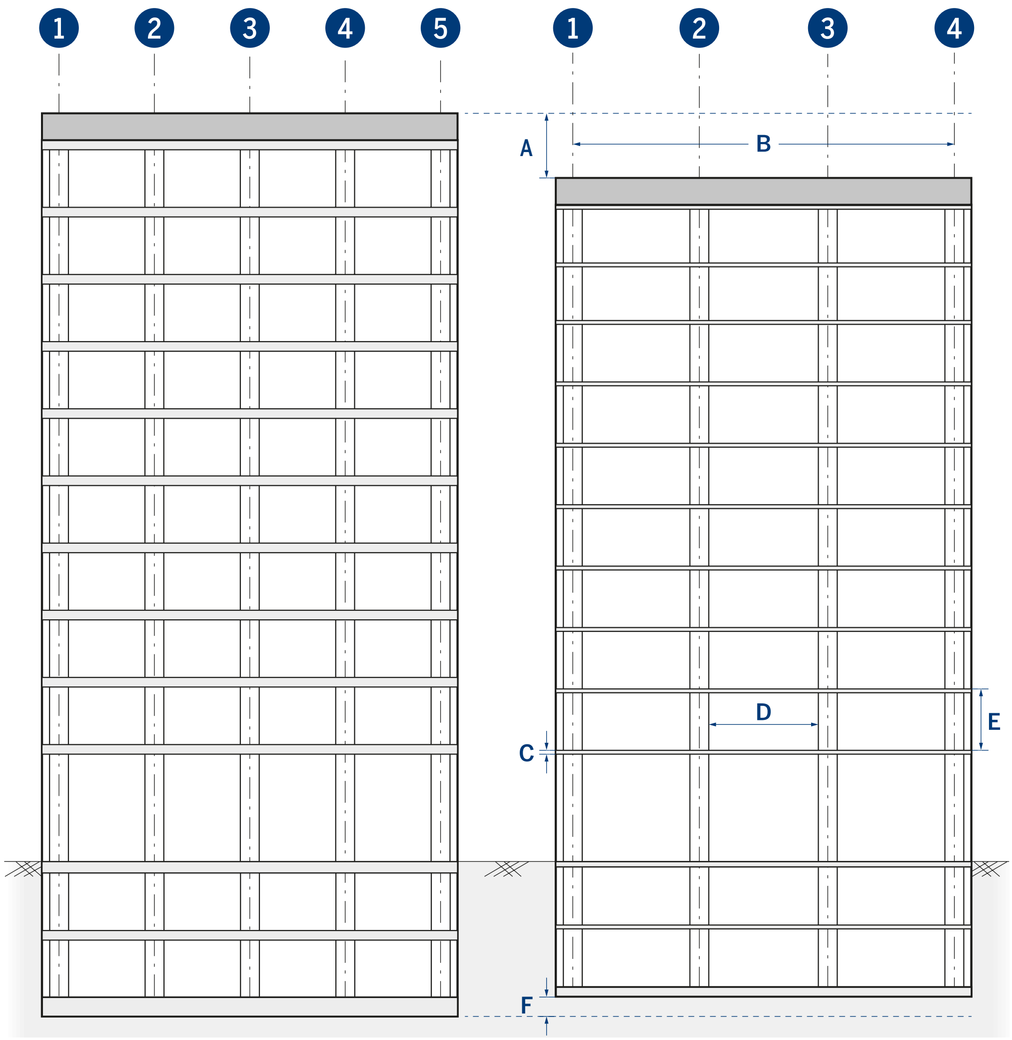
Typical suspended slab applications

- Car parks
- Apartment buildings
- Commercial office space
- Hotels
- Retail centers
- Hospitals
- Stadiums
- Exhibition & convention centers
- Educational institutions such as schools & universities
- Vertical load transfer structures
- Tanks & silos
- Storage facilities

Post-tensioned suspended slabs have become a preferred method in the building construction industry. It has solved the conflicting needs for long spans and minimum structural depth. Besides some clear technical advantages its popularity is based on sound economical merits. By choosing a post-tensioned approach for slab construction, the overall building costs as well as the construction time can be reduced.

Key benefits of post-tensioned suspended slabs

- thinner slab thickness resulting in reduced concrete quantity as well as reduced steel reinforcement quantity and simplified arrangement
- floor-to-floor height reduction leads to lower façade costs or the potential to add additional floors within the same overall building envelope as well as reduced basement excavation costs
- the reduced slab weight leads to smaller columns and savings in the foundations
- larger spans between columns are possible which permits a more flexible arrangement of partition walls
- greater column-free areas enhance the aesthetics of the building, increase the net rentable floor area and potentially also increase rental returns
- virtually crack-free slabs with a high level of deflection control enhancing the quality and durability of the structure
- formwork can be removed earlier, therefore the construction time can also be shortened – reducing finance costs and permitting the building to be occupied faster
- expansion joints can practically be eliminated, improving durability of the structure and reducing maintenance costs
- a lighter and lower building reduces lateral forces caused by seismic events
- an environmentally sustainable structural solution reduces the quantity of building materials required.



Traditional reinforced concrete building

Post-tensioned concrete building

Value enhancing benefits:

- Reduced building costs
- Faster construction
- Greater net floor area
- Higher rental returns

Diagram legend:

A. Lower building reducing facade costs or giving the potential to add additional floor levels

B. Fewer columns

C. Thinner floor slabs reducing building materials

D. Larger clear spans between columns creating more flexible floor plans

E. Reduced floor-to-floor height

F. Reduced basement excavation

Applications & benefits

Post-tensioning for slabs-on-grade

Slabs-on-grade are a special type of post-tensioned slab which function as a foundation plate or floor, providing a cost-effective pavement solution. Amongst other benefits, a post-tensioned slab-on-grade allows a reduction in the number of joints, which leads to lower maintenance cost over the design life of the slab.

Typical slab-on-grade applications

- Warehouses
- Distribution centers
- Storage facilities
- Container terminals
- Freezer stores
- Large retail stores
- Airports
- Industrial manufacturing buildings
- Sporting venues
- Water retaining structures
- Pavements
- Residential slabs
- Raft foundation slabs

Factors affecting slabs-on-grade

There are various factors that can affect the performance of a slab-on-grade, particularly industrial slabs, including:

- heavy traffic loading from trucks and forklifts
- heavy loading from stacked material stocks or plant & equipment installations
- high abrasion from vehicular movement
- differential temperature variations
- expansive soils which expand when wet and shrink when dry.

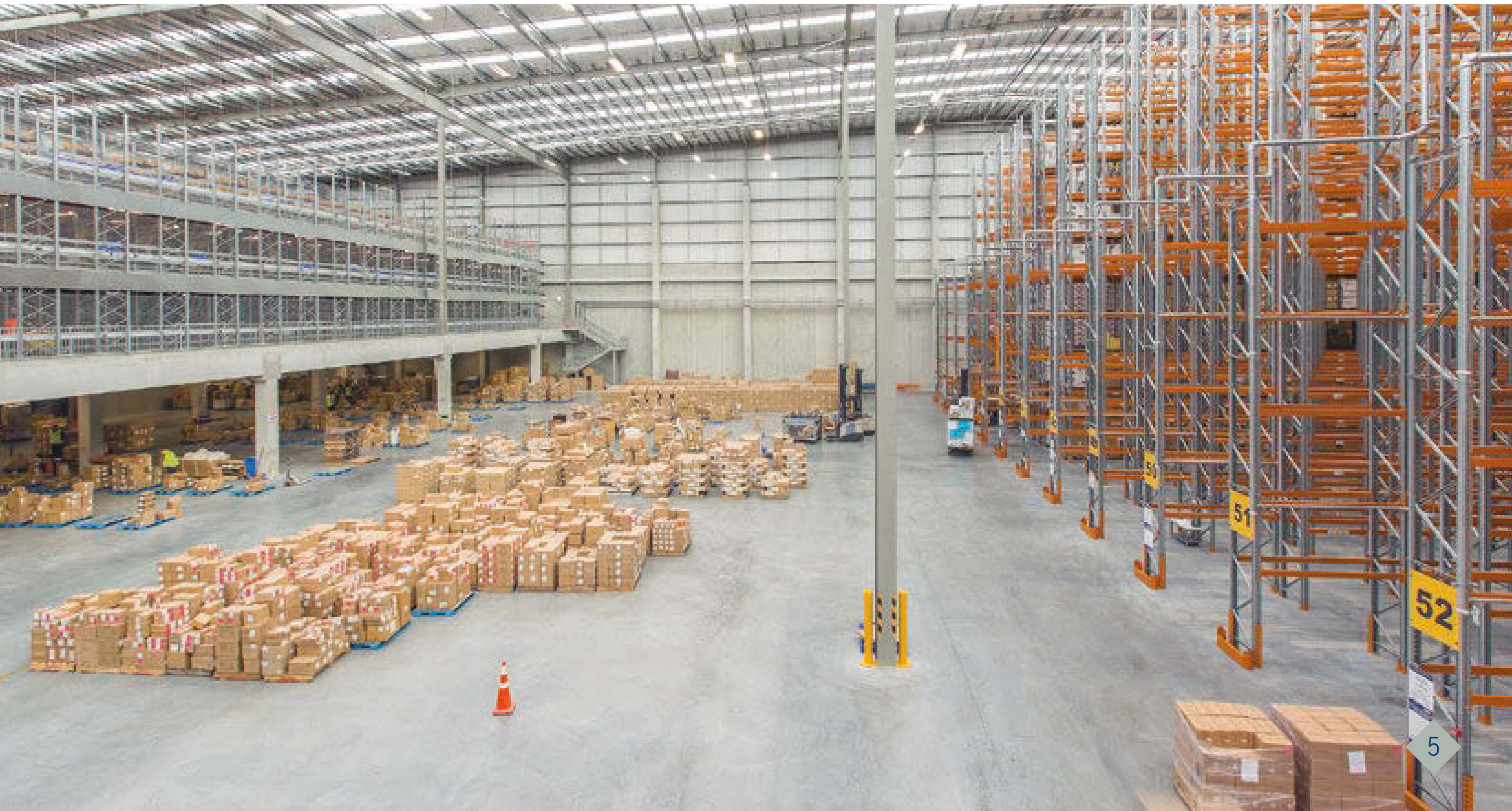
These factors can lead to conventionally reinforced concrete slabs or steel fiber reinforced slabs to experience excessive cracking, spalling, deformation and general damage. If left unchecked, the consequences of these failures can become very expensive for owners and tenants. Loss of productivity from large areas of floor becoming unusable due to an increased requirement for maintenance of the floor joints, slabs that require repair works, increased maintenance and repair of equipment such as forklifts and, in extreme cases, even the forced closure of the entire facility.

By harnessing the benefits of a post-tensioned slab-on-grade, the typical failures highlighted opposite can be greatly diminished. With fewer joints and superior crack control, less maintenance is needed to the floor while producing a smoother ride for forklifts and other loading equipment. In addition a post-tensioned slab-on-grade is ideally suited to receive special finishings and coatings, which can be purely functional or decorative. Different finishings and coatings are possible depending upon the desired appearance, texture, smoothness and durability. For instance various levels of mirror polish finishing, quartz finishing as well as different types of epoxy, polyurethane or acrylic coatings are possible.

Key benefits of post-tensioned slabs-on-grade

Besides some of the same economical benefits as mentioned with suspended slab applications, there are some additional special aspects worth mentioning here:

- large joint-free slab areas (free of saw cuts)
- reduced risk of cracking and crack formation
- enhanced water tightness/resistance properties
- reduced on-going maintenance costs and lower downtime in facilities
- superior performance in weak ground conditions
- less sub-base preparation and reduced excavation needed for thinner slabs
- increased load-carrying capacity of the floor
- flatter slabs with better deflection control, particularly suited to very high narrow aisle shelving systems
- reduced construction materials and lower construction costs
- faster construction time
- more durable floors that are significantly better at resisting wear and abrasion.



How post-tensioning works

Material function and performance

At its most basic level, post-tensioning (PT) is a fiendishly clever way of reinforcing concrete while you are building – occasionally even allowing the construction of something which might otherwise have been impossible!

The use of post-tensioning allows thinner concrete sections, longer spans between supports, stiffer walls to resist lateral loads and stiffer foundations to resist the effects of shrinking and swelling soils. First, we need to have a look at concrete.

Concrete

Concrete has what engineers call 'compressive' strength. As soon as you introduce the 'live' loads of everyday usage, such as vehicles in a car park or on a bridge, the concrete deflects or sags which leads to cracking, thus weakening the structure. Concrete lacks 'tensile' strength. Alone, it does not always offer the flexibility needed. That's why steel reinforcing bars – 'rebar' – are embedded in the concrete to limit the width of cracks. However, rebar provides only passive reinforcement – that is, it does not bear any load or force until the concrete has already cracked.

This is where post-tensioning comes in. Post-tensioning kits provide active reinforcement. The function of post-tensioning is to place the concrete structure under compression in those regions where load causes tensile stress. Post-tensioning applies a compressive stress on the material, which offsets the tensile stress the concrete might face under loading.

As an extension to this, when the post-tensioning tendon is curved to a specific profile, in addition to placing the concrete structure under compression, a beneficial upward (or downward) force will be applied to counteract applied loads to the structure such as the gravity loads. This is known as load balancing.

Post-tensioning tendons

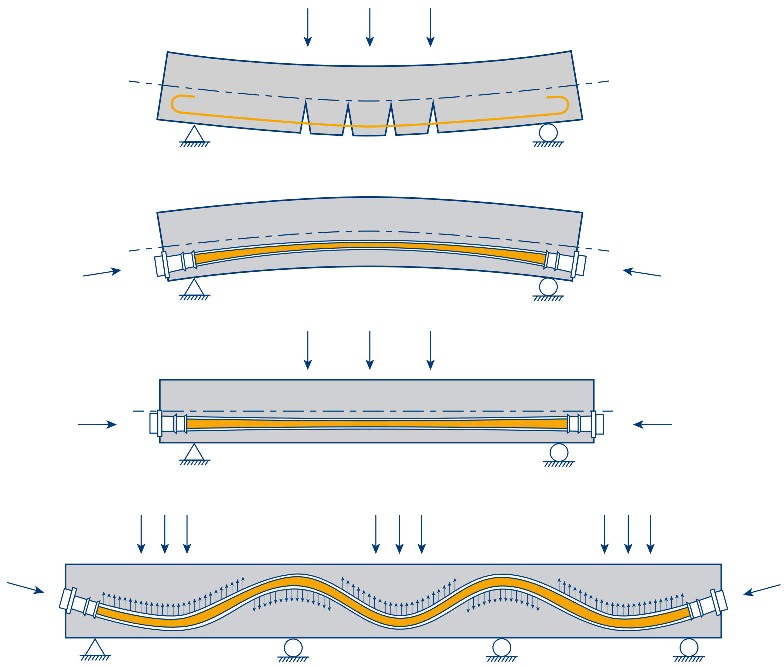
Post-tensioning, or more commonly referred to as simply PT, is applied by the use of post-tensioning 'tendons' – a complete assembly includes a number of individual tensile elements made of high strength prestressing steel, the sheathing or protective ducting, plus any grout or corrosion-inhibiting filler surrounding the prestressing steel and the anchorages needed at both ends.

Tensile elements

The individual tensile elements are made of ≈5mm diameter wires or strands – comprised of 7 wires – in sizes of 12-16mm diameter. They have a tensile strength around four times higher than an average non-prestressed piece of rebar.

Sheathing & ducting

Sheathing or ducting houses individual tensile elements. This allows them to move as necessary when the tensioning force is applied after the concrete cures. The steel stretches as it is tensioned and it is locked into place using an anchoring component, thus maintaining the force in the tensile element for the life of the structure.



Types of post-tensioning

A quality BBR solution for every application

Post-tensioning (PT) tendons come in a number of varieties and cover a wide range of applications. BBR offers a complete range of post-tensioning systems covering almost any application in the built environment. These systems represent the latest internationally approved technologies including having European Technical Assessment (ETA) and CE marking. Here are some of the more common types of PT used in suspended slab and slab-on-grade applications.

Internal bonded tendons

This is where one or more tensile elements are inserted into a metal or plastic duct that is embedded in the concrete. By filling the duct with special grout, the tendon is 'bonded' with the surrounding concrete.

Internal unbonded tendons

This is where the prestressing steel is not actually bonded to the concrete that surrounds it, except at the anchorages. They are typically used in suspended slabs and slabs-on-grade for buildings and parking structures, as well as structures where inspection and replacement of the tendons is required.

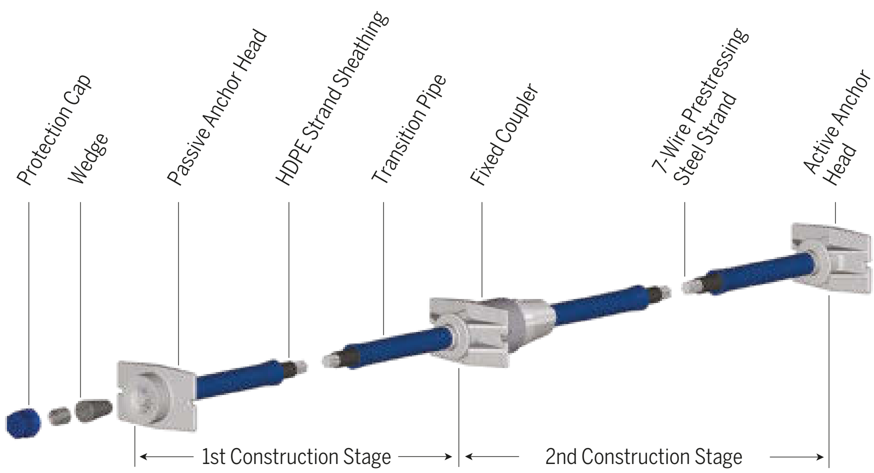
External unbonded tendons

These are installed on the external surface of concrete structures. This type of post-tensioning allows access for maintenance and replacement. This is therefore the solution of choice for building enhancements and refurbishments.

Assuring quality

In the past, there were a lot of national standards – for example, British or DIN standards – and guidelines for testing provisions to which post-tensioning systems had to be subjected. Some of these specifications were very detailed, as a result of local experience – others were not. Some countries adapted and adopted specifications for the acceptance of PT systems running in other countries, others did not have any acceptance criteria at all. Today, post-tensioning technology has a clear international passport if it bears the CE mark and has secured the European Technical Assessment (ETA) for post-tensioning kits.

CE



Design & construction

Post-tensioned suspended slabs

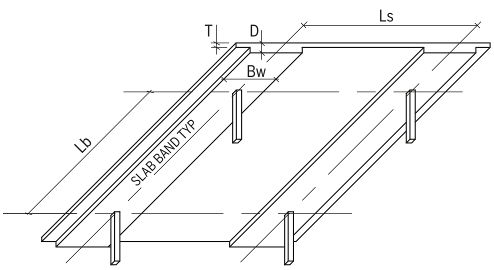
The design of post-tensioned suspended slabs requires considerable engineering knowhow as well as rigorous finite element modeling techniques to maximize the benefits of such a structural solution for all stakeholders in a project. Over the years, the BBR Network has amassed a wealth of experience in designing and detailing PT suspended slabs around the world and has the capabilities to offer design input from initial preliminary advice all the way to detailed design and execution of works.

Floor systems

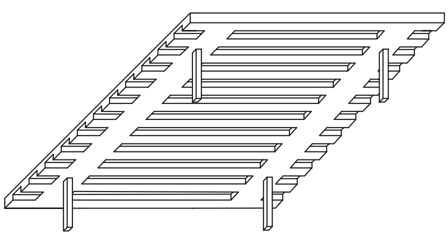
A designer can choose from a multitude of different floor systems. These can be broadly classified into two categories – one-way floor systems and two-way floor systems. The final selection will depend on a number of factors, the main ones being:

- span length between columns
- ratio of floor span length in one direction to the other direction (L1 vs. L2)
- loading criteria, particularly live loading
- constructability with respect to type of formwork available/used
- flexibility of layout of mechanical/electrical services in the ceiling space
- deflection limit criteria
- whether the soffits of the floor slabs will be exposed.

One-way floor systems

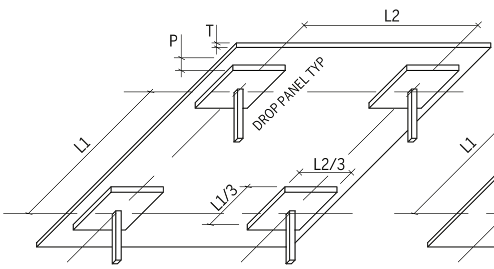


Banded slab

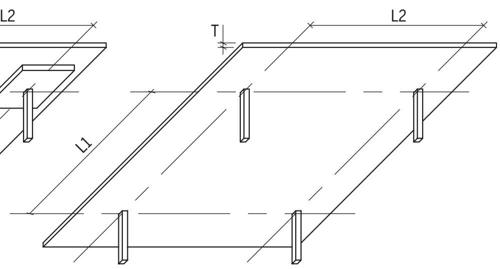


Ribbed slab

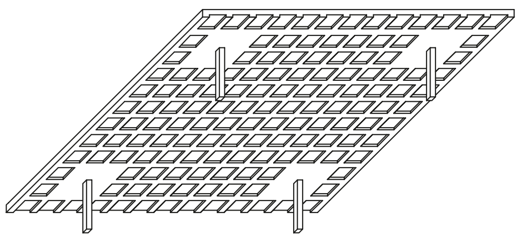
Two-way floor systems



Flat slab



Flat plate



Waffle slab

Definitions

Lb	Band span
Ls	Slab span
L1	Span length in direction 1
L2	Span length in direction 2
L	Design span (greater of L1 & L2)
T	Slab thickness
D	Overall band depth
Bw	Band width approx. (to suit formwork)
P	Overall drop panel depth (1.8xT)

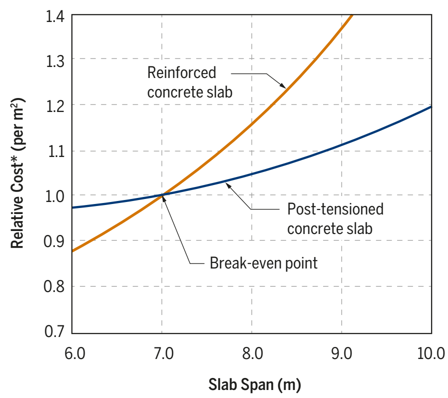
Note: For slab end spans, add 15-20% to slab thickness

Figure 1 : Some typical floor system configurations.

Span to slab/beam thickness selection

Some practical points should be considered early in the preliminary planning stage. The economy of post-tensioned slabs is greatly influenced by the span layout and slab or beam thickness. As it is uneconomical to vary the prestress level (this would require more anchorages) a span layout requiring the same level of prestress in every span should generally be the economical solution. Some rules based on theoretical considerations are:

- internal spans should be approximately equal
- external spans should approximately 0.8 times the length of internal spans
- cantilevers should not exceed 0.3 times the length of the adjacent span
- expansion joints, unless formed with double columns (completely separated slabs), should be approximately in the quarter span locations
- the size of slabs between expansion joints should be limited to a maximum of around 60m (larger distances are also possible).



*Relative cost is an approximation and varies by region.

Figure 2: Comparison of costs – traditionally reinforced concrete slab versus post-tensioned concrete slab.

Primary considerations beyond structural strength are deflection and vibration in selection of slab/beam thickness. Accurate selection of preliminary structural thickness can minimize analysis and design by eliminating the trial and error procedures inherent to the design of continuous structures. The below charts indicate recommended slab/beam thicknesses with respect to span length and design loadings for the most common post-tensioned floor systems.

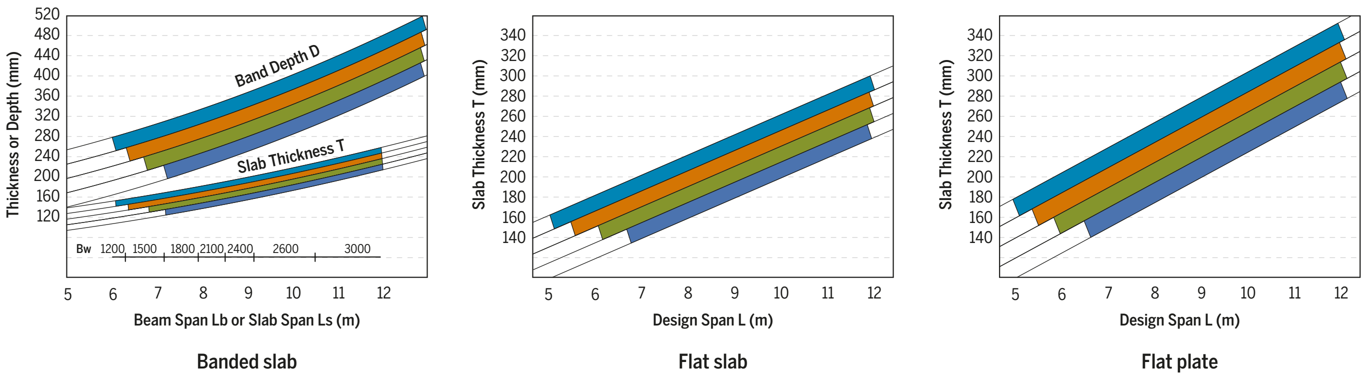


Figure 3: Recommended slab/beam thicknesses with respect to span length and design loadings for the most commonly adopted PT floor systems.

Typical design loads

Colour Reference	Live Load	Super-Imposed Dead Load
	5kPa	1kPa
	4kPa	1kPa
	3kPa	1kPa
	2.5kPa	0.5kPa

Definitions

Lb Band span
Ls Slab span
L Design span (greater of L1 & L2)
T Internal slab thickness
D Overall band depth
Bw Suggested band width approx. (suit formwork)
P Overall drop panel depth

Note: For slab end spans, add 15-20% to slab thickness from charts

Tendon layout

There is considerable design flexibility when it comes to tendon layout and profiling. This is where having BBR onboard to advise on the most cost-effective layout can bring significant cost savings to a project. Some common layouts of tendon distributions in flat slabs are shown in Figure 4. Other distributions can also be considered depending upon constructability issues and code requirements.

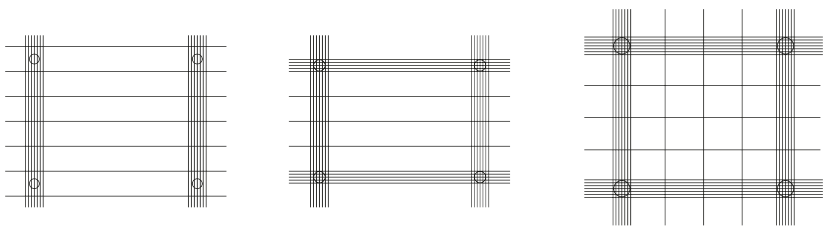


Figure 4: Common tendon distribution layouts.

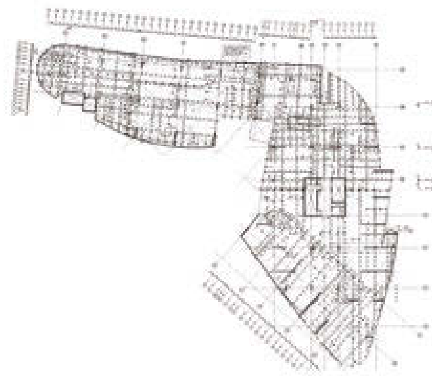
Analysis & design

Post-tensioned concrete slabs are typically designed to satisfy local code requirements for limits on the concrete working stress – service limit state (SLS) and ultimate limit state (ULS). The load balancing method, since its development, was found to be the most convenient way to design post-tensioned slabs. Analysis of the slab for unbalanced and ultimate loads is performed by the equivalent frame method (EFM) or even more sophisticated techniques such as the finite element method (FEM) to obtain the most economical post-tensioned slab design. Stresses and deflections under SLS conditions are checked against the allowable values nominated in the local design codes while critical sections are checked under ULS conditions. Where there is a lack of strength in the slab, additional localized reinforcement is used. Punching shear is also checked and if the strength is insufficient, additional reinforcement or shear studs are added, or drop panels are added to increase the concrete thickness.

Finite element mesh

Stress distribution

Tendon layout



Final drawing

Detailing of post-tensioned slabs

Local anchorage zone detailing is often encumbered by congestion of reinforcement. With the BBR VT CONA CMX range of post-tensioning systems, the application of the full post-tensioning load can be achieved at the lowest concrete strengths using the closest tendon center spacing and smallest concrete edge distance on the international marketplace whilst at the same time using the least amount of local zone anti-bursting reinforcement.

In fact BBR has recently developed several new PT systems specifically for applications in PT slabs that completely eliminate the need for local zone reinforcement. Please refer to the BBR VT CONA CMM and CMF systems on pages 14 to 17. Working tables for the local zone detailing can be found in the respective European Technical Assessment (ETA).

For other areas of a post-tensioned slab, structural detailing is often an art that engineers develop over time with the experience of local building practices and is an essential part of a cost-effective, reliable and durable structure. A selection of tried-and-tested details that the BBR Network has adopted for a range of situations are shown in Figure 6.

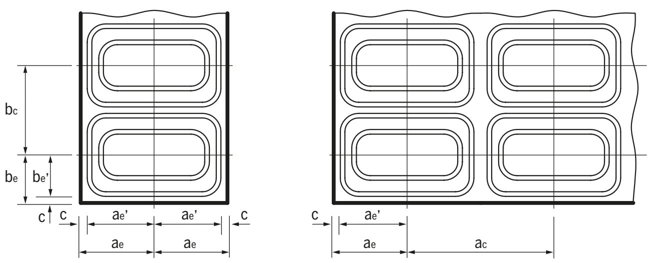
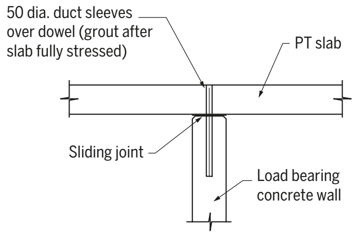
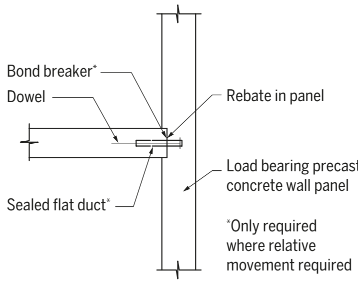


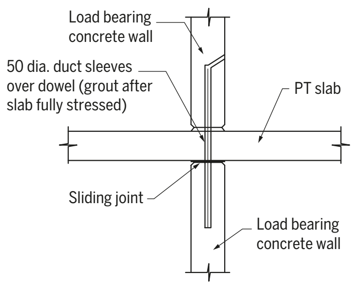
Figure 5: Dimensions of tendon center spacing and concrete edge distance.



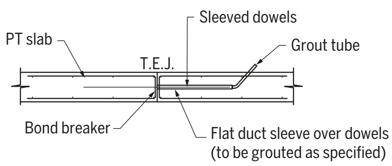
Load bearing wall under – PT slab/beam



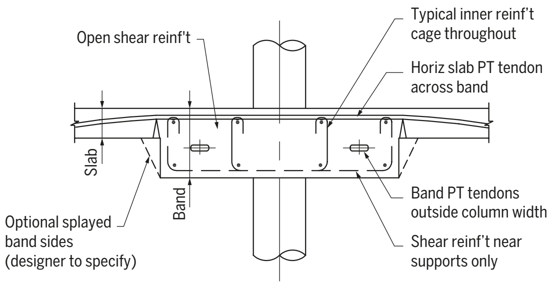
Load bearing wall – precast



Load bearing wall over and under – PT slab/beam



Temporary expansion joint detail



Typical slab band section

Figure 6: Typical structural detailing that has been applied by the BBR Network.

Construction

The speed of construction can be affected by a number of factors, therefore it is important that all parties involved on site have an appreciation of the post-tensioned slab construction process.
Over the years, BBR engineers have worked very closely with builders and construction workers – this has resulted in a well-understood process and through further close collaboration has led to enhancements in efficiency, as well as better and safer working practices. A number of additional considerations – such as prefabrication of tendons, reduction in quantity of reinforcement to be fixed, larger pour sizes and earlier formwork stripping – help to speed the construction process.

A typical construction sequence is as follows:

- erect formwork
- install bottom steel reinforcement
- install post-tensioning tendons to specific profiles
- install top steel reinforcement
- prepour inspection and pour concrete
- strip edge forms
- initial/partial stressing of tendons
- final/full stressing of tendons
- obtain engineers approval and cut off excess strands from tendon
- seal the ends of the live post-tensioning anchors with either mortar or grout caps
- grout the tendons (only applicable for bonded tendons)
- strip formwork and back prop as required.

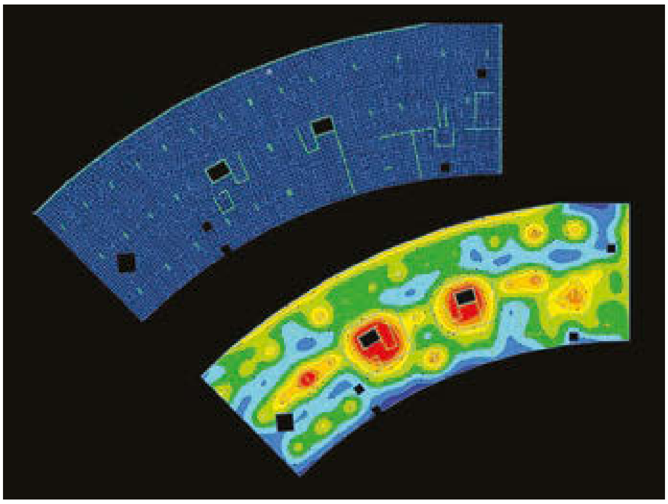
Design & construction

Post-tensioned slabs-on-grade

The design of post-tensioned slabs-on-grade requires the careful optimization of the total costs to the client for the entire structure. Not only are there the costs of the slab itself, but there are also the costs of the excavation and groundworks. As part of this evaluation, considerable analysis is needed of the loads applied to the slab, the soil-structure interaction between the slab and the ground that supports it, restraining forces and temperature effects. After decades of experience in designing and executing post-tensioned slabs-on-grade, BBR has been able to achieve outstanding results and optimum solutions for all stakeholders.

Analysis & design

Finite element method (FEM) analysis can be used to assess the loads applied to the slab – from uniformly distributed loads to more concentrated loadings from racking storage and wheel loads from lifting equipment. The complex soil-structure interaction requires modeling of the sub-base parameters with geotechnical data such as CBR and/or the modulus of sub-grade reaction. Other loading conditions to consider include thermal differential effects from the daily ambient temperature variations, concrete shrinkage and sub-grade frictional restraint stresses between the slab and the sub-grade supporting it.



Finite element mesh and deflection diagram of a heavily loaded raft foundation slab

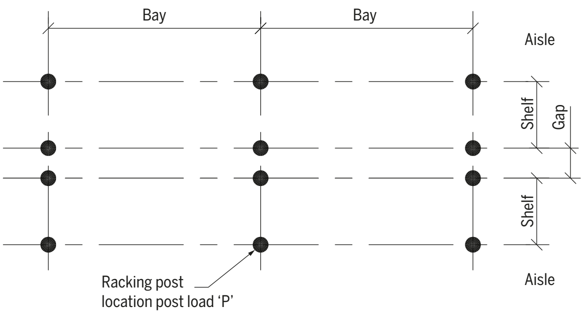


Figure 7: Typical design racking layout.

Definitions

P Design axle load
W Wheel spacing

Other considerations include axle load repetition (2 or 4 wheels etc) and wheel contact pressure

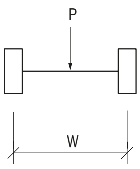
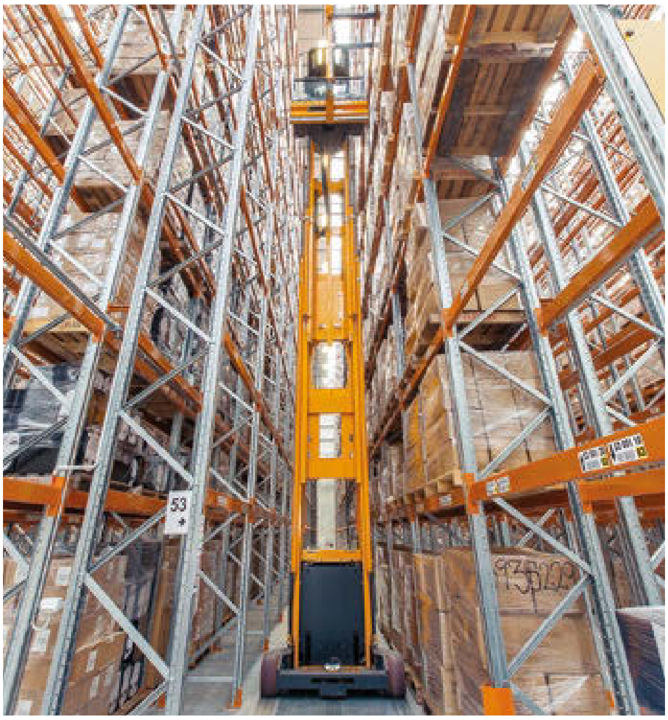
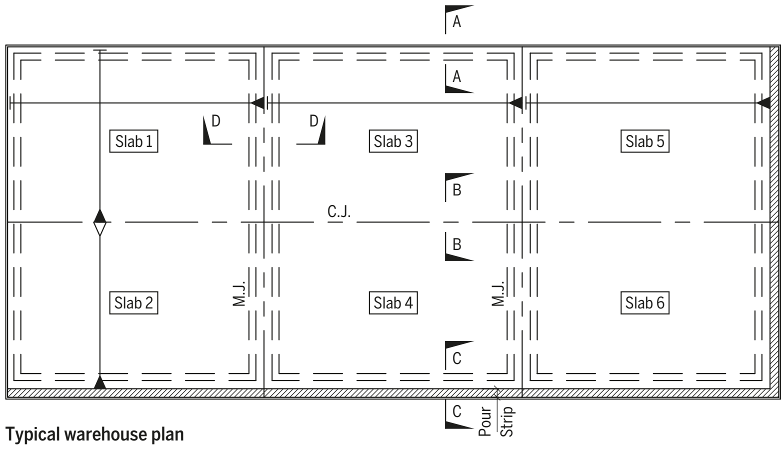


Figure 8: Design wheel/axle details.

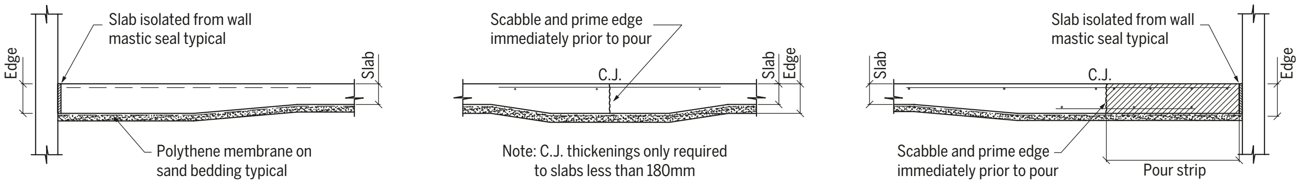


Detailing

An industrial slab-on-grade should be suitably flat, free of excessive cracking, durable and capable of withstanding the required racking storage and traffic loads. In addition, the location and spacing of joints should be either minimized or preferably entirely eliminated, therefore good detailing of a post-tensioned slab-on-grade is critical. Figure 9 shows a typical post-tensioned slab-on-grade layout plan along with some typical structural design details.



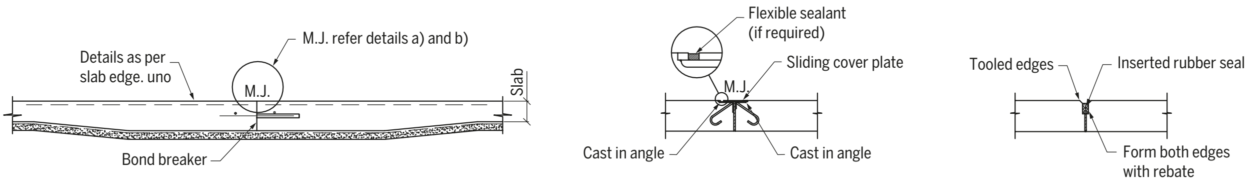
Typical warehouse plan



Section A – A
Typical slab edge detail

Section B – B
Typical construction joint detail

Section C – C
Typical pour strip detail



Section D – D
Typical movement joint detail

a) Steel armoured joint

b) Compression seal joint

Note: As a guide (will vary in different locations), allow for total slab edge and M.J. movements of approximately 0.5mm per meter length of slab (e.g. for 60m long slab, each edge moves approx. 15mm over the nominal life of the slab)

Figure 9: A typical post-tensioned slab-on-grade layout plan, showing some typical structural design details.

Construction

The construction techniques employed by the BBR Network have been developed and refined over many years of experience. A combination of excellence in design and on-site efficiency delivers a seamless installation process. Key considerations for the construction phase are:

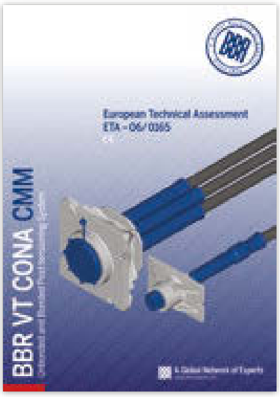
- size of concrete pour
- sequence of concrete pour
- concrete curing time
- protection against weather.

With pour sizes of between 1,500m^2 and 3,000m^2, optimization of concrete pouring and stressing sequences ensures a time-efficient performance. Where large pours are to be made, the slab will initially be susceptible to shrinkage effects and thus it should be protected from extreme heat, high evaporation or extreme cold weather conditions. A typical technique employed to provide some protection is the installation of a warehouse roof prior to concrete pouring.

Post-tensioning technology

BBR VT CONA CMM monostrand post-tensioning system

The European approved BBR VT CONA CMM post-tensioning system is used in internal unbonded or bonded applications with 1, 2 or 4 strands. The system has been optimized to feature lighter anchorages and offer designers the smallest available tendon center spacing and concrete edge distance for stressing at the very low concrete strength of 18/22MPa. It also includes features which accelerate installation and thus reduce material and labor costs.



Features

- Available in either 1, 2 or 4 strand anchorage configurations
- Compact lightweight anchorages optimized for either 12.9mm or 15.7mm diameter, 1,860MPa strand
- No local anti-bursting or splitting reinforcement required at the anchorage
- Application of full post-tensioning force at very low concrete strengths $f_{cm,0}$ = 18/22MPa
- Advanced proprietary monolithic anchorage for very small tendon center spacings and concrete edge distances
- Even smaller spacings are achievable when local anti-bursting reinforcement (either stirrups or helix cage) is added, by using an innovative support chair to centralize the reinforcement
- Monolithic coupling anchorage with an integrated, preinstalled wedge
- Option of using intermediate anchorages eliminating the need for couplers to join tendons on sequentially poured concrete slabs
- Superior corrosion protection ensured with a threaded transition pipe
- In unbonded applications, greased/waxed and individually HDPE sheathed monostrands are used
- In bonded applications, round corrugated galvanized steel or plastic ducts are filled with a high performance BBR grout
- Restressable & exchangeable tendons perfectly suited to long-term inspection and maintenance
- European Technical Assessment and CE marking

Anchorage A – CONA CMM Single S1

Anchorage A – CONA CMM Single S2

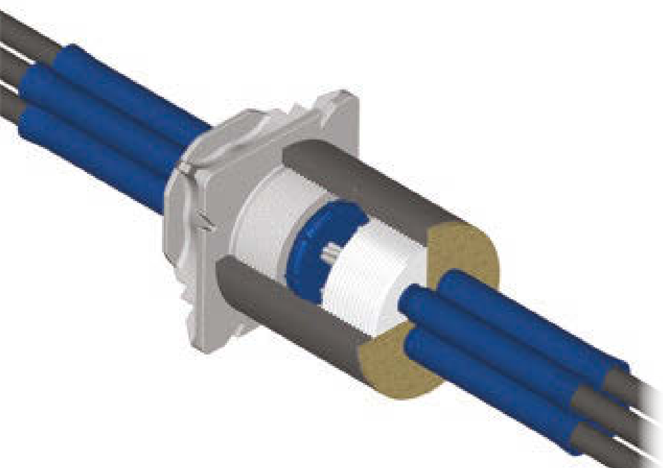
Coupler H – CONA CMM Single S1

Coupler T – CONA CMM Single S2

Anchorage A – CONA CMM Four S1

Intermediate Anchorage I – CONA CMM Single S2

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



Coupler H – CONA CMM Four S1

Available tendon sizes

Type of strands*

in	*05*		06		06C
mm	12.5	12.9	15.3	15.7	15.2
mm^2	93	100	140	150	165
MPa	1,860	1,860	1,860	1,860	1,820

Tendon sizes

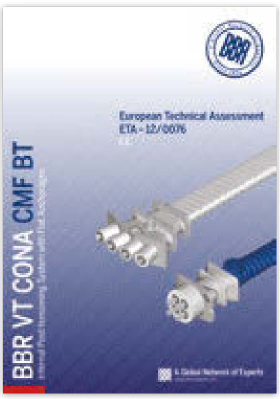
Strands	Characteristic ultimate resistance of tendon [kN]				
01	173	186	260	279	300
02	346	372	521	558	601
04	692	744	1,042	1,116	1,201

*1,770MPa tensile strength strand is also available

Post-tensioning technology

BBR VT CONA CMF flat post-tensioning system

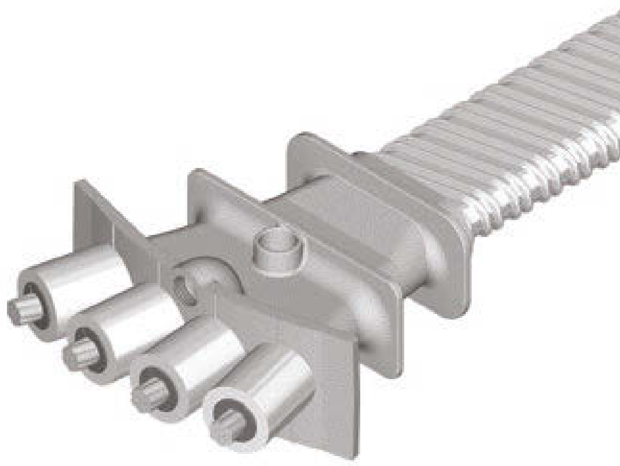
The European approved BBR VT CONA CMF post-tensioning system is a flat multi-strand technology for internally post-tensioned bonded or unbonded applications in very thin concrete cross-sections. The system has been optimized to offer designers the smallest available tendon center spacing and concrete edge distance for stressing at very low concrete strengths, the lowest being 17/21MPa. It also includes features which accelerate installation and thus reduce material and labor costs.



Features

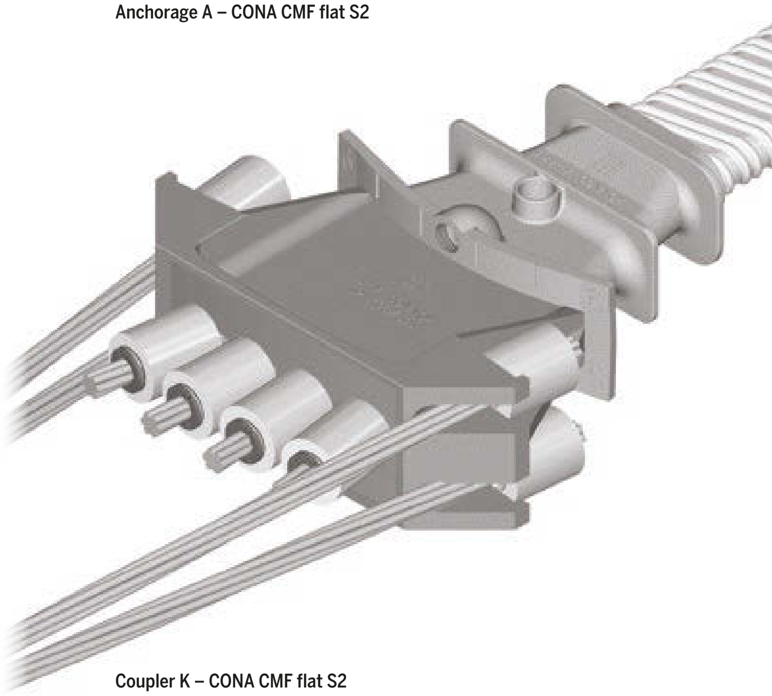
- Anchorages available with configurations from 2 up to 6 strands
- Compact lightweight anchorages optimized for either 12.9mm or 15.7mm diameter, 1,860MPa strand
- Application of full post-tensioning force at very low concrete strengths $f_{cm,0}$ = 17/21MPa (CONA CMF S1)
- Advanced proprietary load transfer element for very small tendon center spacings, concrete edge distances and the thinnest slab thickness
- Fixed and movable couplers for joining tendons
- Corrugated round or flat tendon duct utilizing either galvanized steel or plastic material
- For bonded applications the ducts are filled with high performance BBR grout
- For unbonded applications the ducts can be injected with grease/wax or circulating dry air
- System is compatible with greased and HDPE sheathed monostrands
- Restressable & exchangeable tendons perfectly suited to long-term inspection and maintenance
- European Technical Assessment and CE marking

Anchorage A – CONA CMF flat S1



Anchorage A – CONA CMF flat S2

Coupler H – CONA CMF flat S1



Coupler K – CONA CMF flat S2

Available tendon sizes

Type of strands*

in	05		06	
mm	12.5	12.9	15.3	15.7
mm²	93	100	140	150
MPa	1,860	1,860	1,860	1,860

Tendon sizes

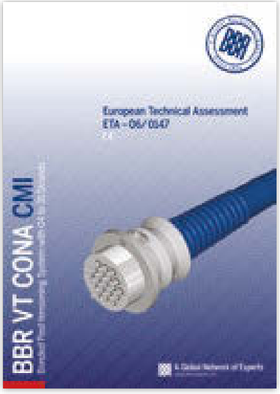
Strands	Characteristic ultimate resistance of tendon [kN]			
02	346	372	521	558
03	519	558	781	837
04	692	744	1,042	1,116
05	865	930	1,302	1,395
06	1,038	1,116	–	–

*1,770MPa tensile strength strand is also available

Post-tensioning technology

BBR VT CONA CMI internal multi-strand post-tensioning system

The European approved BBR VT CONA CMI internal bonded or unbonded post-tensioning system is the most advanced multi-strand PT technology on the international marketplace with tendon sizes from 1 to 73 strands as standard. The system has been optimized to feature compact anchorages and offer designers the smallest available tendon center spacing and concrete edge distance for stressing at the very low concrete strength of 19/23MPa. The CONA CMI system is typically used in buildings for heavily loaded transfer beams, transfer plates and raft foundations.



Features

- Standard tendon sizes from 1 to 73 strands, larger sizes on request
- Widest range of tendon sizes with the largest tendon forces available on the international marketplace
- Optimized for 15.7mm diameter, 1,860MPa strand
- The most compact & lightweight system available utilizing an advanced proprietary load transfer element for very small tendon center spacings and concrete edge distances
- Application of full post-tensioning force at very low concrete strengths $f_{cm,0}$ = 19/23MPa
- Fixed and movable couplers for joining tendons
- Corrugated or smooth round tendon duct utilizing either galvanized steel or plastic material
- For bonded applications the ducts are filled with high performance BBR grout
- For unbonded applications the ducts can be injected with grease/wax or circulating dry air. Greased and HDPE sheathed monostrands in grout filled ducts are also possible
- Restressable & exchangeable tendons perfectly suited for long-term inspection and maintenance
- European Technical Assessment and CE marking

Anchorage A – CONA CMI

Coupler H – CONA CMI

Coupler K – CONA CMI

Note: Other anchorage and coupler types also available. Contact your nearest BBR representative.

Available tendon sizes

Type of strands*

in	05	06
mm	12.9	15.7
mm^2	100	150
MPa	1,860	1,860

Tendon sizes

Strands	Characteristic ultimate resistance of tendon [kN]	
01	186	279
02	372	558
03	558	837
04	744	1,116
05	930	1,395
06	1,116	1,674
07	1,302	1,953
08	1,488	2,232
09	1,674	2,511
12	2,232	3,348
13	2,418	3,627
15	2,790	4,185
16	2,976	4,464
19	3,534	5,301
22	4,092	6,138
24	4,464	6,696
25	4,650	6,975
27	5,022	7,533
31	5,766	8,649
37	6,882	10,323
42	7,812	11,718
43	7,998	11,997
48	8,928	13,392
55	10,230	15,345
61	11,346	17,019
69	12,834	19,251
73	13,578	20,367

*12.5mm and 15.3mm diameter strand and 1,770MPa tensile strength strand is also available

Post-tensioning technology

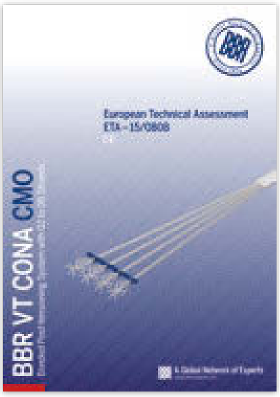
BBR VT CONA CMO onion bonded anchorage

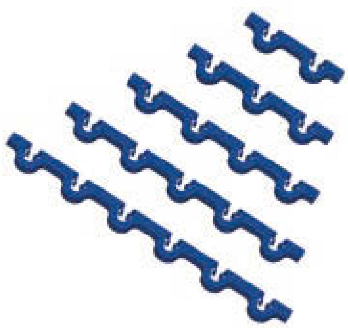
The European approved BBR VT CONA CMO is a multi-strand bonded anchorage with an array of onion-bulb strand ends for internally post-tensioned applications particularly in very thin concrete cross-sections such as slabs. CONA CMO technology offers engineers the possibility of very small center spacing and concrete edge distances without the need for local anti-bursting reinforcement.

BBR VT CONA CMO anchorage

Features

- Standard tendon sizes from 2 to 6 strands
- Optimized for 12.9mm and 15.7mm diameter, 1,860MPa strand
- No local anti-bursting or splitting reinforcement required at the anchorage
- Innovative clip-lock strand spacer and duct sealing filler enhances productivity on site
- Application of full post-tensioning force at very low concrete strengths $f_{cm,0}$ = 21/26MPa
- European Technical Assessment and CE marking





Available tendon sizes

Type of strands*

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

Tendons 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

*1,770MPa tensile strength strand is also available

"We are what we repeatedly do;
excellence, then, is not an act but a habit."

Aristotle
Ancient Greek philosopher and scientist
c.384 - 322 B.C.

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