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Fifth Edition 2011

Upgrading dam safety

Strengthening of three dams to meet new seismic event standards

Birth of an icon

Innovative tilting arch bridge benefits from BBR stay cable technology

Balancing the advantages

Reflection on cantilever construction methods and their application

Launching in Southern Africa

Incrementally launched bridges take off in Africa

Back to our roots

Modern trend for mixed-use developments

THE MAGAZINE OF THE GLOBAL BBR NETWORK OF EXPERTS

A Global Network of Experts

www.bbrnetwork.com

The BBR Network is recognized as the leading group of specialized engineering contractors in the field of post-tensioning, stay cable and related construction engineering. The innovation and technical excellence, brought together in 1944 by its three Swiss founders – Antonio Brandestini, Max Birkenmaier and Mirko Robin Ros – continues, more than 60 years later, in that same ethos and enterprising style.

From technical headquarters 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

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, DINA, SWIF, BBR E-Trace and CONNAECT – 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 60 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); Spennteknikk International AS (Norway), a member of the KB Group (Norway); BBR Pretensados y Tecnicas Especiales PTE, S.L. (Spain), a member of the FCC Group (Spain).

There is much to celebrate alongside this, the fifth edition of CONNAECT magazine – not least, the scope and quality of the work being carried out by BBR Network Members around the globe. Without doubt, our customers have appreciated the benefits of implementing schemes with our technology and know-how.

The quality of our communication is also a major feature of the success we enjoy and this is the theme for Talking BBR this time around. Combine this with the ability of our people to react to customer needs – for example, with the need for dam strengthening works in the light of new seismic standards or, for example, the need to remove obstacles to keep a power station running – then our services become a compelling proposition.

We can also celebrate the dedication to professionalism shown by our teams of specialists. In Poland, massive developments are underway, while in Spain, there is a relentless drive to provide infrastructure for the new high speed rail link and, in Africa, new highway infrastructure is being built to support communities – all this with the help of the best possible advice and technology from the BBR Network.

As we reflect on the past twelve months' activities, we must also consider ourselves extremely fortunate to be in this position – and express our thanks to our people who have worked so hard to maintain uncompromising quality and also to our customers for rewarding us with their business.

Bruno Valsangiacomo
Chairman
BBR VT International Ltd

Marcel Poser
CEO
BBR VT International Ltd

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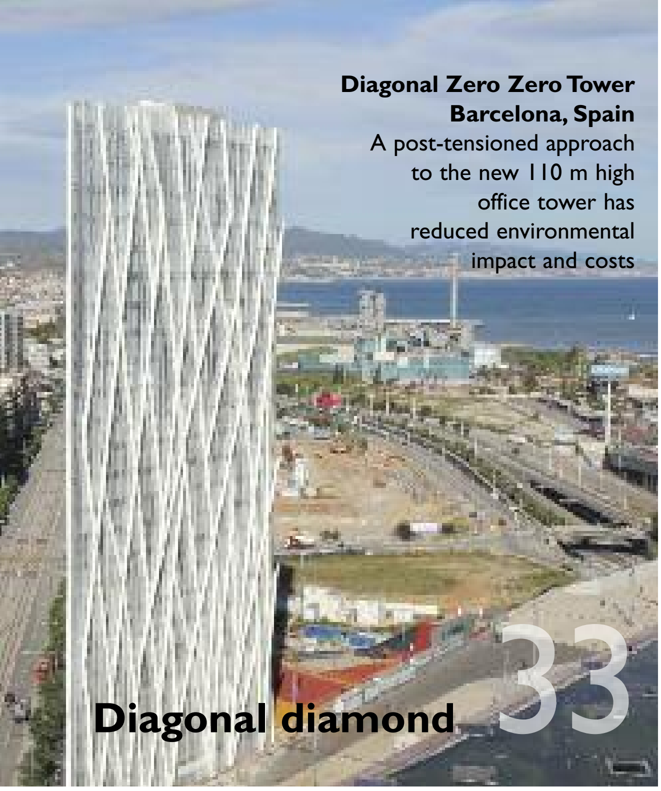

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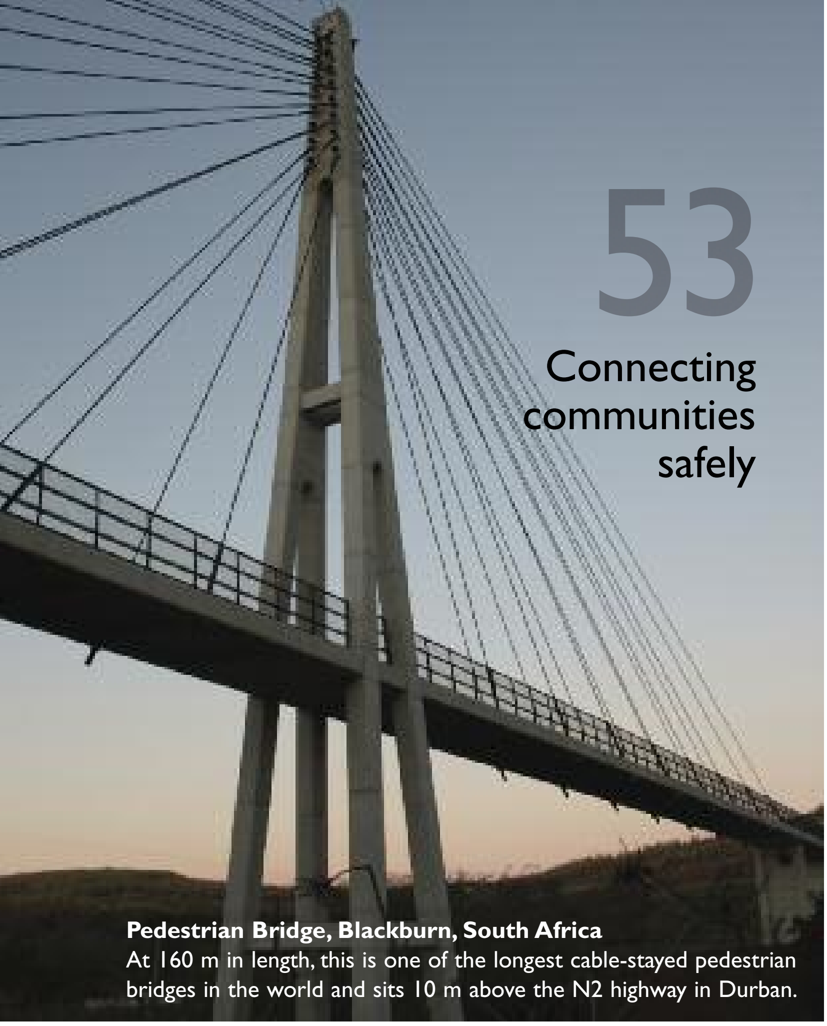

Pedestrian Bridge, Blackburn, South Africa
At 160 m in length, this is one of the longest cable-stayed pedestrian bridges in the world and sits 10 m above the N2 highway in Durban.

Projects in Australia and Norway demonstrate how the application of BBR Technology can provide necessary strengthening to dam infrastructure to meet the new seismic standards.

Wind Towers, Bremerhaven & Hamburg, Germany
Low maintenance, factory preassembled BBR VT CONA CMB bands again prove their suitability for wind tower projects.

Tanks & Silos

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Special Applications

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Cultivating...

The global nature of the BBR Network's business means that ensuring everyone is up to speed with the latest developments and practices requires a special approach. Marcel Poser, CEO of BBR VT International, explains how this works, reflects on events of the past year and offers an insight into forthcoming developments.

WHAT IS YOUR STRATEGY FOR COMMUNICATION?

MP: We talked about 'shared understandings' in the last edition of *CONNAECT* and actually this is key to our communication strategy. By creating a shared understanding – about our products, techniques and best practice – BBR Network Members are able to provide the very highest level of service and our customers also have the opportunity to appreciate the benefits of choosing BBR.

By bringing our global team together for conferences and training, as well as visiting individual BBR Network Members at regular intervals, we can exchange information and best practice. In turn, BBR Network Members represent our product range and expertise directly to our customers who can also see our work first hand on building sites.

OK, so we could just issue policy directives and send out product lists, but these alone would not create the same level of understanding – or indeed inspire individual and collective 'ownership' of the technology.

WHY IS INSPIRING 'OWNERSHIP' IMPORTANT?

MP: Well, it creates a kind of personal bond – a sense of pride even – between the technology and the individual working with it or using it. It's a bit like being a sculptor – anyone can get the materials and tools, but it is the understanding, experience and commitment which produce the fine statue. Many people will know the individual and shared sense of achievement which comes from involvement in a construction project, especially a challenging one – it is this spirit that we endeavor to create in-and-around the BBR Network.

SURELY, QUALITY CONTROL MUST BE A CHALLENGE?

MP: No, not really – but it is, without doubt, a huge and important area for us. As we've said before, even though we are represented in some 50 countries, it is the structure of the BBR Network which ultimately ensures quality for our customers – and, indeed, for our own reputation!

As far as our products are concerned, quality assurance begins with European Technical Approval (ETA). Incidentally, we have been granted approvals in the last twelve months for a further three of our products – BBR VT CONA CMI BT internal, CONA CMI SP internal and CONA CMB band PT – which currently puts BBR in first place, in terms of the number of approvals in Europe. The ETAs are all downloadable from our website.

As the ETA Holder, BBR VT International arranges for the certification of BBR PT Specialists – and there is a continuous review of performance and suitability. We don't just do this ourselves, we seek the support of independent approved bodies to ensure our approach really is in accordance with the requirements.

Beyond this, our online trading platform, BBR E-Trace, further supports the quality control of our products. It leads BBR Network Members through the whole quality process – right from ordering components from our Component Manufacturers to installation on site and the issuing of the definitive CE marking. Our platform offers the ultimate in traceability, it's been a huge success. In fact, we're launching BBR E-Trace version 2.0 shortly and this will offer even more functionality, including, for example, making E-Trace compatible with handheld electronic and mobile devices and providing a comprehensive database of experts and special equipment within the BBR Network.

HOW DO YOU COMMUNICATE WITH CUSTOMERS?

MP: It's actually the BBR Network Members who 'own' the communication, but the BBR Head Office team supports them with marketing or technical material and occasionally also provides project-specific assistance.

A key part of our work within the wider industry involves participating in industry-wide dialogues. For example, we regularly present technical papers at international forums – such as those presented last year at the *fib* Congress.

We firmly believe that this is a vital part of our work and that, by sharing this information, we are also promoting and extending best practice on a worldwide scale.

SO, WHAT'S NEW?

MP: How much space do we have here to write it all down? Seriously now, there are many new developments both within the BBR Network and in the industry generally. For instance, we are seeking further technical approvals including the new flat anchorage PT system – BBR VT CONA CMF – which will be the perfect solution for slab post-tensioning. Furthermore, we will be expanding our European approved CONA CMX family with 05-inch strand anchorages. There are also plans to expand our product range with technology which will complement our standard PT and stay cable offering … but more of that later in the year!

Meanwhile, in the wider domain, new European grouting conformity standards have been introduced. After obtaining the grouting conformity to EN standards for Switzerland – details are in the Technical Insight article on page 49 – we are now certifying BBR grout mixtures to the latest European norms.

The outlook is very exciting, we are looking forward to a very fast-paced twelve months ahead during which we anticipate many new developments and projects. ●

… shared understandings

Effective communication

We take up the theme of 'shared understandings' here and examine the ways in which the BBR Network communicates, both internally and externally. Some of us acquire knowledge best from written texts, some from highly visual material and still others from the spoken word – so, we use a blend of these methods to convey our messages effectively.

Before embarking on this journey, we should first consider why we need to communicate – in a commercial environment, the main driver is obviously the transaction of successful business. So, we must ensure our teams are qualified, equipped and motivated for the roles they will play and, of course, our customers must also be aware of the quality and strength of our products and services.

THE BRANDS

Without strong branding, any communication initiative risks causing confusion at best – and being overlooked at worst. This is a vital issue, because the 'brand image' carries with it all the qualities and attributes associated with that brand – in this case, a picture most definitely paints a thousand words.

We take great care in projecting strong brand images not only for the BBR Network, but also for our products. CONA, BBRV, HiAm, DINA and SWIF are all well-known BBR brands within our industry – and carry with them the expectations of quality, performance and service.

BBR NETWORK MEMBERS

Our people, BBR Network Members, who represent our brands are selected for their leading positions within the industry, experience in design and installation of post-tensioning and related fields – and their professionalism.

From the outset, we set the bar high. We have a four phase certification process which begins with a company's application to become a BBR Network Member. The final phase of our process never ends, as it involves continuous re-evaluation and certificate renewal.

SHARING KNOWLEDGE AND TRAINING

To support BBR Network Members, we organize training seminars and facilitate networking on a global scale which promotes the sharing of best practice and ensures a world class performance wherever construction takes place.

In 2010, for example, we held regional courses and seminars on PT design specifications, CONA CMI BT/SP and CONA CMB European Technical Approvals, procurement, BBR Factory Production Control, grouting to EN 447 standards, testing to ETAG 013 guidelines and more in Bochum, Germany and Dubai.

Our Global BBR Conference is a annual event which brings BBR Network Members together in one place for three days. The agenda always includes technology updates, training and presentations by individual BBR Network Members on specific projects.

In addition, we encourage Regional BBR Network Groups which agree on joint efforts including approaching regional designers and consultants, regional congresses or exhibitions and the submission of tenders for large scale projects. With such close bonds, it is quite common for members to support each other with local experts and draw on the pool of specialized equipment owned within the BBR Network, such as that needed for bridge construction, for example. BBR Headquarters staff make technical or commercial visits to BBR Network Members on a regular basis, as well as supporting members from the tender stage through to execution of a project and facilitating joint ventures between members for major projects.

Of course, our online trading platform, BBR E-Trace now links all BBR Network Members and is a successful and immediate means of communicating effectively with everyone including our Component Manufacturers.

EXTERNAL IMAGE

Ownership of local communication strategies rests with the BBR Network Member in that region. Initiatives include local newsletters, brochures and roadshows, as well as providing support for local designers and contractors. Opportunities to submit tenders for work give members the chance to show their ability to deliver real value to customers, in terms not just of budget, but also of quality and innovation. The best shop window is, however, provided by their construction sites where their professional approach is on display for all to see.

While it is the individual BBR Network Members who are best-placed to communicate directly within their own local market places, BBR Head Office's communication strategy supports them in this task.

LITERATURE & INITIATIVES

Our range of literature includes a portfolio of high quality detailed product and technical literature, plus *CONNAECT* magazine which gives members the opportunity to showcase their work – both to other members and to customers and other construction professionals.

Naturally, these items are all downloadable – along with many other documents such as our European Technical Approvals and project references – from the BBR Network website. The latter is currently being redesigned to deliver all relevant information in a high level and user-friendly web design. Our approach is to allow the required information to be accessed with only a few mouse-clicks.

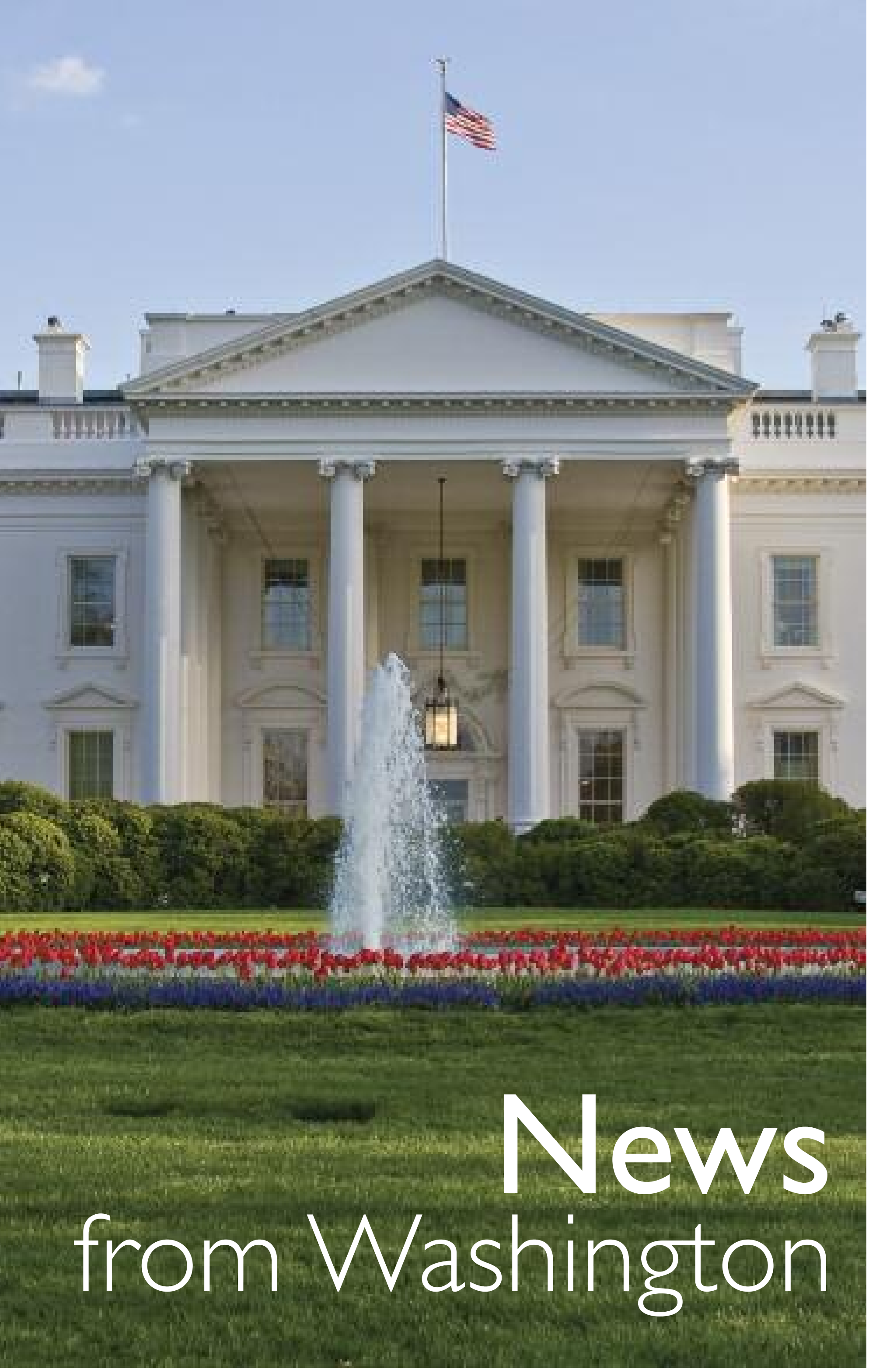
Perhaps less tangible, but of great importance, are the industry initiatives we undertake. We are committed to sharing knowledge with the rest of the industry and often make presentations at global or regional conferences, produce scientific or technical articles for journals and participate on international committees. These activities position the BBR Network firmly at the forefront of construction technology.

Today, the BBR Network has access to some of the finest tools and channels for communication and constantly seeks to improve the quality of both its service and messages. We are continually refining the way in which we communicate to achieve maximum effect for members and our business. ●

Technical papers presented

The technical papers, presented by BBR VT International and members of the BBR Network, demonstrate not only an in-depth understanding of construction technology, but also our dedication to the delivery of quality products and services to BBR customers everywhere. For example, the papers listed below were presented in Washington, D.C. at the *fib* Congress:

- **Workability of a Frictional Damper in a Shallow Cable: Analytical and Experimental Work,** presented by Antonio Caballero, PhD, Head R&D & Marcel Poser, CEO, both of BBR VT International, Switzerland.
- **400 Projects with High Amplitude Fatigue-Resistant Stay Cables,** presented by Marcel Poser, CEO, BBR VT International Ltd.
- **CE-Marked Post-Tensioning Kits: An International Passport for State-of-the-Art Post-Tensioning,** presented by representatives from within the industry – BBR was represented by Marcel Poser, CEO, BBR VT International Ltd.
- **Balanced Cantilever Construction,** presented by Thomas Richli, Dipl.-Ing., BDM, BBR VT International., Jacek Sowa, M. Sc., Site Engineer, BBR Polska, Warsaw, Poland & Chee-Cheong Chang, General Manager, BBR CS (M), Subang Jaya, Malaysia.
- **Post-Tensioning Technology in Sports Arenas,** presented by Thomas Richli, Dipl.-Ing., BDM, BBR VT International, Berislav Medic, Prof., Structural Design Engineer, UPI-2M, Zagreb, Croatia, Kresimir Bogadi, Ing. grad., Project Manager, BBR Adria, Zagreb, Croatia & Bartosz Lukijaniuk, M. Sc., Site Engineer, BBR Polska.
- **Analytical Solutions for the Problem of Cable Bending,** presented by Antonio Caballero, PhD, Head of R&D & Marcel Poser, CEO, both from BBR VT International.



News from Washington

Our Global BBR Conference was held in Washington, D.C. to coincide with the *fib* Congress which was also taking place there. Both events provided an excellent opportunity for BBR Network Members to update each other and themselves on the very latest technology and techniques.

FIB CONGRESS

The *fib* Congress only takes place every four years, so it was particularly important that we maximized our participation. We took an exhibition booth where BBR Network Members were able to welcome a variety of friends and colleagues, both old and new. We presented a number of papers during the Congress, see panel on previous page, and these were well-received by fellow delegates.

GLOBAL BBR CONFERENCE

The day after the *fib* Congress concluded, we adjourned to our own conference in the Hays Adams Hotel in central Washington. There were sessions on CONA CMX and HiAm CONA, a guest presentation by Professor Berislav Medic on design aspects of sports arenas, other agenda items included marketing, training and follow-up discussions based on issues raised at the 2009 Global BBR Conference in Paris. Delegates were entertained by pianists **Dr. Immin Chung Poser** (below) and **Dr. Owen C. Lovell** (below, bottom) who performed a magnificent piano duet, enjoyed by all at the BBR Gala Dinner.

An interesting aside here is that the concert involved two grand pianos – one of which was brought over from the White House, after being played by Sir Paul McCartney the night before. Only the finest instruments are good enough for the BBR Network!

PRESTIGIOUS 2010 *FIB* AWARD

There was also cause to celebrate, as the **Navia Viaduct** project, in Asturias, Spain was honored with a *fib* Award as an outstanding concrete structure in the civil engineering category. Situated in an ecologically sensitive marshland, innovative design and construction techniques were needed to minimize environmental impact. Spanish BBR Network Member, BBR PTE, carried out prestressing work which included the installation of internal and external CONA post-tensioning systems for the deck, as well as BBR stay cables to support both the 160 m long central spans. The precast segments were placed with the cantilevering and advanced shoring methods. However, the Navia Viaduct was not the only BBR Network project to be recognised during the *fib* Awards – the Adriatic LNG Terminal also received a special mention.

CHARITY GOLF TOURNAMENT

Twenty three keen BBR golfers turned out to do battle at the Trump National Golf Course. It was a once-in-a-lifetime experience to play on this legendary course designed by Tom Fazio and Arthur Hills. Our Tournament took place on the River Course which is a par-72 open links-style course winding along the banks of the Potomac River. As in Sydney, we raised money during the event to support the work and activities of the Pestalozzi Children's Foundation – a Swiss children's charity which supports disadvantaged children and young people throughout the world.

GLOBAL BBR CONFERENCE 2011

After a round the world tour which has taken in Dubai, Singapore, Sydney, Paris and Washington over recent years, in 2011, the Global BBR Conference finally comes home to Switzerland. We are looking forward to a lively and informative series of meetings with picturesque mountain scenery as a backdrop and inspiration. ●

The Navia Viaduct project, in Asturias, Spain

TALKING BBR

Money raised at the BBR Charity Golf Tournament was donated to the Pestalozzi Children's Foundation.

BBR Project of the Year 2010

The Zagreb Arena in Croatia was named BBR Project of the Year 2010 for its simple, elegant and efficient structural post-tensioning concept.

Zelimir Bodiroga, CEO of BBR Network Member BBR Adria and Structural Design Engineer of the arena, Berislav Medic, pictured here, were very proud to bring the prestigious award to Croatia this year.

The Zagreb Arena is a multi-functional complex with a seating capacity of 15,200 and hosted the 2009 Men's World Handball Championship. The basic shape and structural elements are prestressed prefabricated reinforced concrete columns with heights of up to 37 m. Eighty-six columns surround the hall, support grandstands and carry the façade, as well as the suspended steel roof structure.

The Zagreb Arena was the outright winner of the 2009 structural design category at the World Architecture Festival. The iconic structure with its inward leaning ribs demonstrates the architectural creativity and durability which is achievable with leading-edge BBR VT CONA CMI internal post-tensioning technology.

VIADUCTS, A8 HIGHWAY, ASTURIAS, SPAIN

Synchronized spans

Four magnificent new viaducts for the A8 highway now sweep through the principality of Asturias in northern Spain, between the villages Las Dueñas and Muros del Nalón. This highway stretches all along the north of Spain, parallel to the coastline of the Cantabrian Sea. David Olivares Latorre of BBR PTE describes how the work was carried out.

Local insight: Cudillero

Reputed to have been first discovered by the Vikings, the attractive coastal village of Cudillero sits in a narrow valley leading to the sea.
Nicknamed the 'amphitheatre', the houses of Cudillero cling to the sides of the mountain surrounding the old fishing port. Today, some 5,000 people live in this picturesque village which has become a focal point for tourism. While the local people speak Spanish, they have their own local dialect, Pixueto, here too.
Many festivals are celebrated in Cudillero – perhaps the best known is the four day L'Amurvela, held in June. The village's history and economy are rooted in fishing and, adjacent to the port, the Plaza de la Marina central square is the hub of activity.

The largest viaduct is called Concha Artedo because of its location next to the Concha Artedo beach within the municipality of Cudillero – a region renowned for fishing. It will be the biggest and highest viaduct built in Asturias.
We carried out two different activities during the viaduct construction – the stressing and the positioning of precast segments.

SEGMENT PLACEMENT AND STRESSING

The bridge has 17 final spans and is built with precast segments to a total length of 1,200 m. We placed the precast segments using the projecting advanced method – achieved with self-launching formwork.
The slab was prestressed with BBR VT CONA CMI internal tendons. Over 940 t of stressing steel was used and stressing was performed with a hydraulic auto-propelled robot that placed the stressing jacks inside the deck.
The slab interior prestressing consists of 700 CONA CMI 1906, 1,032 CONA CMI 2406 and 92 CONA CMI 3106 anchorages.
The precast segments were positioned using four 1,700 t vertical and eight 167 t horizontal synchronized jacks, equipped with force and displacement instrumentation.
A total of 560 precast segments were placed. First, the synchronizing equipment was placed over the piers. Next, the first three precast segments were positioned over the vertical hydraulic jacks. Initially,

the segments were linked by bars. A preliminary positioning was made to verify that the construction was correct. The following step was to place the precast segments that would now be joined with CONA CMI tendons.

SYNCHRONIZED POSITIONING

After the stressing of 35 precast segments, the final synchronized positioning was carried out. This was along a length of approximately 75 m which ran to the middle of the span length. This is known as 'T' section because of its shape. BBR VT CONA CMI tendons were placed and stressed between each pair of 'T' sections.

The self-launching formwork rested in the constructed section, so the construction activity began from one abutment and finished in the next – always continuing in the same direction.

Corrosion protection of the stressed cables was carried out to latest grouting standards.

The construction process was very satisfactory, as we achieved a cycle time of around two weeks for completing each 'T' section.

FURTHER VIADUCTS

There are two further viaducts – San Juan and Piñera – situated on this route. They each have two 55 m long carriageways consisting of seven phases, joined with 2706 FK fixed couplers. For these four bridges, we installed 256 couplers in total.

A fourth structure, the 150 m Santa Ana viaduct, also has two carriageways and, here, we used 32 BBR VT CONA CMI 2706 tendons in its construction.

TEAM & TECHNOLOGY

OWNER Ministerio de Fomento
MAIN CONTRACTOR FCC Construcción S.A.
TECHNOLOGY PT bar
BBR VT CONA CMI internal
Balanced cantilever
BBR NETWORK MEMBER BBR PTE, A.S. (Spain)

"THE CONSTRUCTION PROCESS WAS VERY SATISFACTORY, AS WE ACHIEVED A CYCLE TIME OF AROUND TWO WEEKS FOR COMPLETING EACH 'T' SECTION."

In best Roman tradition

LANGDEEL AQUEDUCT, FRIESLAND, NETHERLANDS

Aqueducts often look more like tunnel structures than the classic bridge structures that the Romans were famous for constructing. Not so the Langdeel Canal Aqueduct in Friesland, where connoisseurs can find a classic aqueduct in its purest form. Ben Grundlehner of Netherlands-based BBR Network Member Spanstaal, takes up the story.

A welded PVC foil construction formed the basis for a new section of Dutch polder and the concrete that dominates many other aqueducts has been hidden away under green slopes. The whole thing thus blends perfectly into the wide-open Frisian landscape that surrounds it. Construction and design have come together and brought an aqueduct back to basics – conveying water over a road.

PROJECT BACKGROUND

Even in the clear expanses of the Frisian countryside, roads and canals do battle for the space available. At the Langdeel aqueduct over the N31 between Leeuwarden and Drachten, the two forms of transport cross one another`s paths. Ballast Nedam Infra, BAM Civil and Dura Vermeer – who came together in the Wâldwei Construction Consortium – were commissioned by the Dutch Directorate-General for Public Works and Water Management to widen the road and build an aqueduct and two adjacent bridges. Furthermore, they will be responsible for managing and maintaining the whole project for the next 20 years.
Ensuring a fast and safe flow of traffic was the number one priority. The customer, the Dutch Directorate-General for Public Works and Water Management, took an important step towards more market initiatives with this, the first DBFMO (Design, Build, Finance, Maintain, Operate) contract ever to be commissioned in our country. Chris Vegter, architect at the Dutch Directorate General for Public Works and Water Management, was instructed to draw up a design memorandum for the section of the N31 where the Langdeel Aqueduct is now located.

In focus: Langdeel Aqueduct

The Langdeel Aqueduct forms part of the project to widen the N31/Wâldwei between Drachten and Leeuwarden – through a Design, Build, Finance, Maintain, Operate (DBFMO) arrangement – doubling the Nijegasterhoek-Hemriksein road section.
The section of the Wâldwei between Nijegaasterhoek and Hemriksein was one of the few trunk roads in our country that had not yet been widened to two lanes on each carriageway which was compromising the road safety. In addition, traffic was being delayed at the Fonejachtbrug bridge, where the Wâldwei crosses the Prinses Margriet Canal, part of the main Lemmer-Delfzijl connection. During the summer months in particular, this connection is a popular route for pleasure vessels, meaning that the bridge often had to be opened.
The construction of the Langdeel Aqueduct as part of the 'Staande Mast Route' (route for ships with tall masts) has now relieved the Prinses Margriet Canal of much of its pleasure cruising traffic. The contract was awarded to the Wâldwei.com b.v. Special Purpose Company and the design build, management and maintenance is in the hands of the Wâldwei v.o.f. Construction Consortium. PT works, as well as delivery of joints and bearings, was executed by Spanstaal B.V

FOIL CONSTRUCTION

The decision to incorporate a mini-polder into the project more-or-less made itself – due to the specific requirement that the aqueduct should be integrated into the natural environment. The PVC foil structure also had to stop water from deeper layers and the environment from flowing into the polder. The underpass below the aqueduct – and therefore the foil construction too – had to be able to accommodate the widening of the N31 from two single to two dual carriageways in each direction. The foil construction was designed with a length of 800 m and a width increasing from 40 to

200 m. The deepest point is an approximate Amsterdam Ordnance Datum -24 m. The aqueduct itself is 110 m long and 25 m wide.

SUPERSTRUCTURE

The superstructure, with a total length of 110 m, consists of six aqueduct sections with a width of 25 m. The outer sections have been placed high, completely on steel foundations. Sections 2 and 5 are placed high on steel foundations on one side and transfer the load on the other side to columns. The four middle sections transfer all the loads to the underlying columns.

Except for the outer sections, the floors of all sections are post-tensioned in a longitudinal direction. The floors were post-tensioned from one side and included a blind anchoring in the concrete on the other side. BBR VT CONA CMI internal 0706 and 1206 PT tendons were used.

Chief structural engineer Meindert Verwoerd compares the Langdeel Aqueduct with other similar structures. The pure shape of the structure is what stands out according to him. "This is an aqueduct as the Romans intended," he commented with an air of satisfaction. It should be clear to everybody that something very special has been built, far away in the north of our country. ●

TEAM & TECHNOLOGY

OWNER Directorate-General for Public Works and Water Management

MAIN CONTRACTOR Wâldwei Construction Consortium

TECHNOLOGY BBR VT CONA CMI internal

BBR NETWORK MEMBER Spanstaal B.V. (Netherlands)

AMMAN DEVELOPMENT CORRIDOR, JORDAN

Quality on time

The Government of Jordan secured a loan from the Arab Fund for Social and Economic Development (AFSED) towards the cost of Amman Development Corridor – Phase 1 and part of these funds are being applied to Contract 1 of this project. Tendering was open to prequalified firms only and Ali Kurdi of Jordan-based BBR Network Member **Marwan Alkurdi & Partners** reports that his company had successfully prequalified as the nominated subcontractor for Bridge Works.

Contract 1 involves the construction of approximately 18.5 km of the Amman Ring Road, between Desert Highway Road and South of Madounah Road. The project aims to construct a closed corridor dual carriageway with two 3.65 m lanes in each direction, 3 m hard shoulders plus 0.5 m verges and a 4.5 m wide central reservation with new jersey median barriers. The total roadway width is 26.1 m with a minimum right of way of 80 m. Climbing lanes are also included, where applicable. The Overpass OP7 was designed to pass over the new construction highway – the bridge is 9.6 m wide and consists of three spans (20 m, 41.2 m, 20 m) with total length of 81.2 m.

ENSURING FIRM FOUNDATIONS

The overpass is founded on deep large diameter piles and to ensure adherence to quality control and specification requirements, pile load testing was carried out – one preliminary and two working pile tests. Additional tests were carried out to ensure the integrity of the drilled piers where low-strain sonic testing was conducted on approximately 25% of the installed piers. There were also further tests on all the single piles underneath the pile caps to evaluate pier integrity.

PT SUPERSTRUCTURE

The superstructure for this overpass was cast in-situ post-tensioned voided slab. The post tensioning system consisted of 12 tendons, each tendon containing 19 strands. The tendons were stressed in pairs from both ends simultaneously, in accordance with the project specification and design requirements. ●

TEAM & TECHNOLOGY

OWNER Ministry of Public Works and Housing

BRIDGE CONTRACTOR Marwan Alkurdi & Partners

DESIGNER Dar Alhandasah (Shair & Partners)

MAIN CONTRACTOR Copri Construction Enterprises EST

TECHNOLOGY BBR VT CONA CMI internal

BBR NETWORK MEMBER Marwan Alkurdi & Partners Co. Ltd (Jordan)

DANUBE RIVER BRIDGE,
TRAISMAUER, AUSTRIA

Commuter CONNECTION

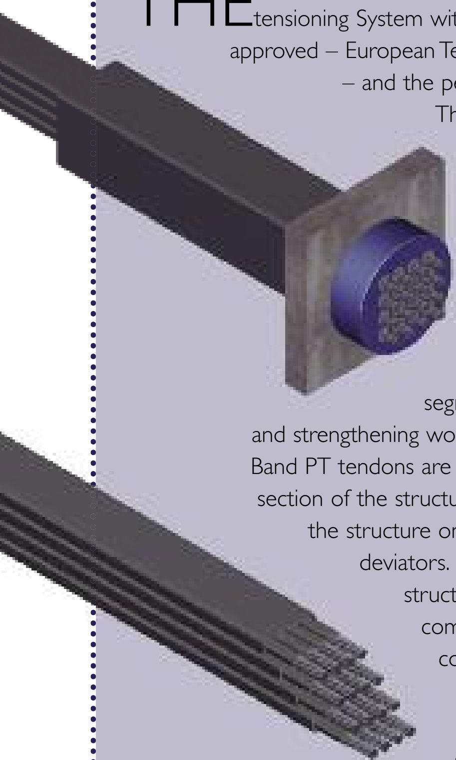
A few miles east of the beautiful world cultural heritage landscape of Wachau – also one of the best wine growing regions of Austria – a new high-performance direct public transport link between the northern and southern central areas of Lower Austria has been created. Norbert Bogensperger of Austrian BBR Network Member Vorspann-Technik outlines the project and his company's work.

The new Danube bridge close to Traismauer is at the heart of the new 6.6 km road link. It consists of the foreland bridges south (330 m) and north (360 m) and the main bridge over the Danube with a length of 360 m. The latter consists of three spans – two 99.5 m side spans and a 156.2 m main span. This configuration ensures the required width of 150 m in the centre to preserve the shipping lane.

FLOATING PILLAR INNOVATION

An innovative technology – applied for the first time in Austria – saw the basic pillar stages prefabricated as they floated between pontoons. They were then floated to the

Technical insight: BBR VT CONA CMB band system



THE BBR VT CONA CMB SP Unbonded Band Post-tensioning System with 01 to 16 strands is European approved – European Technical Approval ETA-10/0065 – and the perfect ready-to-use PT solution. The innovative double HDPE sheathed and greased/waxed approach of the CONA CMB system makes it the most suitable PT solution for special external applications, such as the prestressing of bridges, wind towers, precast segmental construction and repair and strengthening works for all kinds of structures. Band PT tendons are placed outside of the cross-section of the structure and transfer the forces to the structure only at the anchorages and deviators. They are not bonded to the structure. The band system can be combined with a broad range of construction materials – including concrete, steel and timber – and offers a broad range of advantages:

- Monitoring, inspection and maintenance can be easily carried out.
- Option for restressing, destressing and replacing.
- Improved concrete placing and tendon installation.

The CONA CMB PT kit is a multi-strand system with standard tendons sizes from 01 to 16 seven-wire prestressing strands. Most commonly, standard 0.62" (15.7 mm) strands or compacted 0.6" (15.2 mm) strands are used.

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

The anchorages are the Type S stressing/active anchorages and the Type F fixed/passive anchorages. For restressable and exchangeable tendons, excess strand length is required at the anchorage and requires permanent corrosion protection.

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

The strands are greased/waxed and individually sheathed in the factory with a continuously extruded HDPE sheathing and subsequently grouped parallel and then contained within an additional extruded smooth rectangular plastic sheath.

pier locations and placed into their final positions in the 13 m deep water.
Following production of 48 bored piles – ranging from 120 to 45 m high – the pillars were concreted. The structural height of the pillars reaches 8.4 m and decreases to 3.8 m – the height only remains constant for the last 24.3 m of the span towards the pillar.

BALANCED CANTILEVER CONSTRUCTION

Both carriageways were constructed separately, using the balanced cantilever method. Each carriageway consists of a single-cell hollow box girder with 9 m wide cantilever sections on both sides. The overall width of the bridge is 31.5 m.
In addition, a combined pedestrian and bicycle path is planned in the form of a suspended steel construction underneath the cantilever plates east of the Vienna lane. This will cater for up to 5,000 people who use the cycle paths along the Danube daily.
Single section lengths of the balanced cantilever construction were between 3 and 5.2 m long, which corresponds to a total weight of 1,900 kN.

INTERNAL AND EXTERNAL PT

Our contract included the supply of BBR VT CONA CMI 1506 anchor heads for the internal post-tensioning, as well as the complete installation of the external post-tensioning where we applied the BBR VT CONA CMB 4x04 150/1,770 system. This system allows the bands to be used continuously, in one piece, throughout the total length of the bridge – thus they have a single length of 353.7 m. For durability, the installation must allow for adjustability and replacement of the bands – as a result, cover caps of the anchor heads are 2 m long. ●

TEAM & TECHNOLOGY

OWNER
ASFINAG (Austrian National Motorway Authority)
MAIN CONTRACTOR Alpine Bau GmbH
DESIGNER Josef Mayer ZT GmbH
TECHNOLOGY
BBR VT CONA CMI internal
BBR VT CONA CMB band
BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH (Austria)

PETERSTRASSE RAILWAY BRIDGE, HANNOVER, GERMANY

EXPRESS DECK DELIVERY

The Peterstrasse Bridge, in the Hainholz area of Hannover, is a part of the trans-European high-speed rail network and greatly increased rail traffic loads, as well as serious damage to the structure, meant that it needed to be replaced. Dennis Koch from German BBR Network Member, Spankern, describes the solution.

The old bridge consisted of a vaulted superstructure dating back to 1847 and which had been constructed for the then Hannover-Minden line. In addition, there were steel superstructures created in 1914 for the route to Langenhagen.
The special feature of this project was that, with the high frequency of intercity express trains, manufacturing had to take place beside the existing live railway tracks. The completed superstructures were then pushed into place as a finished component. Both superstructures consist of a longitudinal post-tensioned deck slab with a construction height of 1.1 m and supported width of 17.4 m.
The new structure is post-tensioned with BBR VT CONA CMI 1906-140 tendons. In the northern superstructure, 15 tendons were placed and we placed 19 tendons in the southern superstructure. ●

TEAM & TECHNOLOGY

OWNER DB Netz AG, RB Nord
MAIN CONTRACTOR
H.F. Wiebe GmbH & Co. KG
DESIGNER DB Projektbau GmbH, RB Nord, Regionales Projektmanagement
TECHNOLOGY
BBR VT CONA CMI internal
BBR NETWORK MEMBER
Spankern GmbH (Germany)

A8 Motorway Wrocław Bypass

Rapid development of infrastructure in Poland, powered by financial support from the European Union, started few years ago and still continues at a brisk pace today. In this feature, Bartosz Łukijaniuk of BBR Polska reports on the significant role his company has been playing to speed along the infrastructure renewal program.

In recent years, BBR Polska has taken part in many road projects – including bridges, viaducts, flyovers and motorway junctions – this is our main business. While our work on major infrastructure projects attracts the most publicity, we have also carried out work on many other roads and bypasses – involving numerous structures. Four of our recent projects are described here. Two more large infrastructure projects – Grudziadz and Maluszyn – are featured as separate reports in this edition.

1 BIELSKO-BIAŁA NE BYPASS

Bielsko-Biała city's north-eastern bypass is one of the most important infrastructure projects in the south of Poland. The bypass joins express road S1 (north-south) with express road S69 in the Bielsko-Biała suburbs. The road travels though numerous valleys – Bielsko-Biała is one of the biggest cities in the Beskidy mountains region. The terrain is a major hindrance – and other problems include numerous landslips.
BBR Polska was contracted for 12 engineering structures on this project. The WS10 flyover is the largest of these and consists of four main viaducts – each having 11 spans of lengths between 35 and 45 m. This structure was executed on a span-by-span basis. The total length of the WS10 flyover is 460 m. In addition, seven access flyovers were also constructed.
Structure WS5R is another large flyover – it is 414 m long and consists of two viaducts, each with 11 spans of lengths between 31 and 39 m. Meanwhile, the WS5N flyover is 335 m long. It consists of two flyovers, each with eight spans and covering a total length of 335 m. There were nine other structures, between 45 and 110 m long on the project.
The north-eastern bypass of Bielsko-Biała city is the largest contract carried out by the team from our regional office in Gliwice, Silesia. In total, we used 2,025 t of stressing steel on this project.

Structural **strength**

1

1 2

2 A1 MOTORWAY, BEŁK TO SWIERKLANY

The A1 motorway will run from Gdansk, in the north of Poland, via central Poland to the Silesia region in the south and beyond to the border with Slovakia. The section from Bełk to Swierklany leads from the Silesian agglomeration to the border. Within this project, we were contracted for 24 structures. The largest structure we executed was MA502 – consisting of two eight span post-tensioned concrete flyovers and constructed by the span-by-span technique. Span lengths are between 30 and 40 m, while the total length is 301 m. Structure MA502 is post-tensioned longitudinally with BBR VT CONA CMI and transversally with BBR VT CONA CMM tendons. For the whole contract, 960 t of stressing steel was used.

3 A8 MOTORWAY WROCŁAW BYPASS

This motorway bypass is a part of the A8 motorway that goes around the western side of Wrocław. This section is almost 27 km long and links the S8 express road (north of Wrocław) with the A4 motorway (south of Wrocław). The largest structure here was WA17 – two separate seven span motorway flyovers, each of approximately 300 m in length. Construction of the superstructure was carried out using incremental launching technology. There were 12 segments in each of the two flyovers and span lengths were between 29 and 60 m. This structure is post-tensioned with BBR VT CONA CMI longitudinal tendons, BBR VT CONA CMM transversal tendons. The project was completed in December 2010.

4 SKARZYSKO-KAMIENNA BYPASS

The new section of the Skarzysko-Kamienna S7 express road is 16km long. This project consists of 17 large civil engineering structures. The largest is a 290 m long flyover made up of three individual structures – each of which is an eight span flyover with span lengths of 25 + 6x40 + 25 m. We used 640 t of stressing steel for this structure. These are just a few of the projects in which BBR Polska has taken part. In the past year alone, many more infrastructure projects have been executed with BBR Technologies – for example, bypasses of cities such as Lubliniec, Siewierz, Serock, Poznan, Minsk, Mazowiecki and Warsaw. These – and also future projects here, in Poland – will benefit from the advantages offered by the BBR product range and know-how. ●

TEAMS & TECHNOLOGIES

1 2 3 4

OWNER General Directorate for National Roads and Motorways

TECHNOLOGY
BBR VT CONA CMI internal
BBR VT CONA CMM monostrand
Expansion joint
BBR VT TOBE pot bearing

BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

1 BIELSKO-BIALA NE BYPASS

MAIN CONTRACTOR Hermann Kirchner Polska Sp. z o.o. / Mosty Łódz S.A. / Intercor Sp. z o.o.

DESIGNER consortium led by Mosty Katowice Sp. z o.o.

2 A1 MOTORWAY, BELK TO SWIERKLANY

MAIN CONTRACTOR Strabag Sp. z o.o. / Heilit Woerner Sp. z o.o.

DESIGNER consortium led by Trakt Sp. z o.o.

3 A8 MOTORWAY WROCLAW BYPASS

MAIN CONTRACTOR Strabag Sp. z o.o. / Dywidag Bau GmbH

DESIGNER consortium led by Arcadis Profil Sp. z o.o.

4 SKARZYSKO-KAMIENNA BYPASS

MAIN CONTRACTOR Strabag Sp. z o.o. / MOTA-ENGIL Central Europe S.A.

DESIGNER Mosty Katowice Sp. z o.o.

NEW UNDERPASSES, PODGORICA, MONTENEGRO

Crossing the lines

Podgorica's new bypass crosses the Beograd-Bar railway line, as well as the tracks of the Podgorica-Tuzi line and Podgorica Aluminum Plant's industrial railway at an angle of 90 degrees. Approximately 120 m south-east from there, the Zetatrans industrial railway passes beneath the bypass at a 36 degree angle. Krešimir Bogadi, Operations Department Manager of Croatia-based **BBR Adria** explains that the contract terms, as well as the conditions of Montenegro Railways required that these crossings should be made in two levels by using underpasses.

FIRST UNDERPASS

The first underpass, at Zetatrans, was designed and built as a two-span bridge with five girders across the spans. The girders were cast next to the site in half sections and then mounted into place. Then, the strand was inserted in the ducts and the two girder sections were fixed together by stressing the tendons. We used a total of 20 BBR VT CONA CMI internal 1506 tendons.

SECOND UNDERPASS

The second underpass was designed and built in seven segments. Each segment is a multi-cell post-tensioned box structure with three BBR VT CONA CMI 1506 tendons in each web. A total of 210 BBR VT CONA CMI anchorages were used to finish the project. As only one 24-hour possession of the railway line was permitted, the first three segments were prefabricated next to the site and shifted sideways into position. During the possession, the old railway tracks were removed and replaced with new ones. The remaining four segments were then cast in-situ using traditional formwork.

TEAM & TECHNOLOGY

OWNER
District of Podgorica & European Commission

MAIN CONTRACTOR STRABAG d.o.o.

DESIGNER CDS d.o.o.

TECHNOLOGY
BBR VT CONA CMI internal

BBR NETWORK MEMBER
BBR Adria d.o.o. (Croatia)

ALKARAK–ALQATRANAH HIGHWAY BRIDGE, AL KARARK, JORDAN

Jordan's second highest bridge

The Ministry of Public Works and Housing wanted to improve the entrance to the city of Al Karark and considered various options, taking into account local, environmental and topographical impacts. Ali Kurdi of Jordan-based BBR Network Member Marwan Alkurdi & Partners explains that, after a period of detailed research and design, invitations to tender for the 'Al Karark Entrance Project' were sent to five prequalified Jordanian contractors – and his company won the bid.

The main purpose of the project was to enhance the approach to the city of Karark by removing hazards, such as slopes and curves, in the existing road.

There were many elements to this project including a 177 m long bridge over the wadi Al Thanyyah – which, at 42 m high, is believed to be the second highest bridge in Jordan.

In addition, there were two new underpasses to link the main highway with another road. The new 1,850 m long road is a dual carriageway, with two 3.6 m traffic lanes on each side and complete with central reservation, barriers, sidewalks and 1,314 m of safety/guard rails. We were also responsible for installing the drainage systems and 700 m long retaining walls

In the casting yard, which had been prepared behind Abutment B, we manufactured a total of 55 precast post-tensioned concrete girders – 22 girders were 34.9 m long and the remaining 33 were 34 m in length. We selected the BBV VT CONA CMI internal post-tensioning system for this task. The girders were erected using a 40 m /100 ton launching girder.

TEAM & TECHNOLOGY

OWNER
Ministry of Public Works and Housing

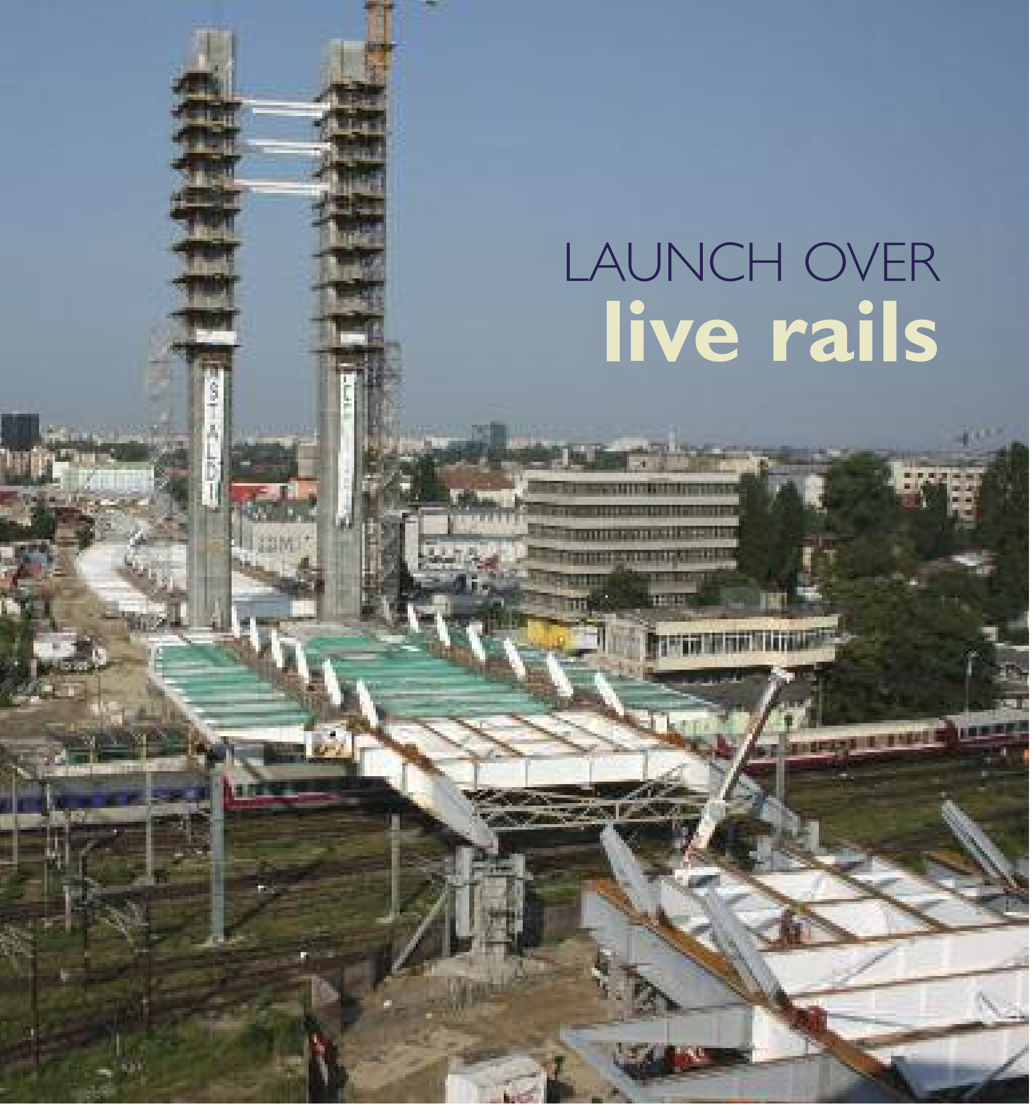
MAIN CONTRACTOR Marwan Alkurdi & Partners Co. Ltd

DESIGNER Engicon – Jordan

DESIGN REVIEW
Dar Alhandasah (Shair & Partners)

TECHNOLOGY
BBR VT CONA CMI internal
Advanced shoring

BBR NETWORK MEMBER
Marwan Alkurdi & Partners Co. Ltd (Jordan)



LAUNCH OVER **live rails**

BASARAB OVERPASS, BUCHAREST, ROMANIA

The 1.9 km Basarab Overpass is located in the north of the city of Bucharest. The project crosses railway lines near the North Train Station and runs from the Nicolae Titulescu Road to Grozavesti Road. Gustavo Delgado Martín from BBR PTE, the BBR Network Member for Romania – describes the innovative solution they applied to part of the construction.

We undertook construction of the section of the bridge over railway tracks using launching techniques – as it was impossible to install the steel structure by crane in such close proximity to the live railway network. The total length of bridge deck launched was 58.5 m. This was divided into five phases with a slope of 0%. The total weight to be launched was 15,000 kN. The deck connection was made approximately 23 m from the last pier.

HEAVY LIFTING JACKS

The bridge was launched with four heavy lifting pulling jacks and two heavy lifting retaining jacks. The pulling and retaining jacks each have a capacity of 850 kN, with seven compacted steel strands, and the stroke of each jack is 400 mm. With this capacity of stroke, we reached launching speeds of six meters per hour – and this was a critically important goal because we only had three working hours during possession of the railway line.

All jacks were synchronized. A retaining force was set and, once the pulling force was bigger than the retaining one, the bridge started to move. The movement of the pulling jacks was synchronized in displacement, using the total pulling and retaining force as a control parameter.

LAUNCHING TECHNIQUE

Launching was performed by sliding the bottom flanges of the two metal girders over provisional sliding lifting jacks. These lifting jacks were provided with a guiding system which consisted of two steel structures positioned on both sides of each beam of the deck, interior and exterior, that helped to guide the structure during the launching. The underside of the metal flanges was treated with sliding paint and, during each launching phase, lubricated to prevent excessive friction. We used a pole system to recover the deflection when we reached the pier. This method of construction ensured the project was realized on time, our work on this section of the bridge was completed within two months.

TEAM & TECHNOLOGY

OWNER City Hall of Bucharest, Romania.
MAIN CONTRACTOR Basarab JV (FCC Construcción + Astaldi)
DESIGNER Technical Services of FCC Construcción & Carlos Fernandez Casado, S.L.
TECHNOLOGY Launching
BBR NETWORK MEMBER BBR PTE, S.L. (Spain)

LAUNCHED BRIDGES, SOUTHERN AFRICA

Building launch bridges IN SOUTHERN AFRICA

Paul Heymans of BBR Network Member Structural Systems Africa presents a review of the work being undertaken by his company, set in the context of the local economic and social landscape. A major drive was initiated by South African National Roads Agency Ltd (SANRAL) in 2006 to upgrade the highway network in the Gauteng Province of South Africa. The project became a necessity due to the significant increase in vehicles in-and-around the major cities of Johannesburg and Pretoria. This was partly due to the world-wide economic boom of the early 21st century and South Africa's strong re-entry into the worldwide economic fray – after what were widely considered to be the country's first fully democratic elections in 1994, which saw the election of Nelson Mandela to the presidency.

GAUTENG PROVINCE

With only 1.4% of South Africa's land area, the tiny province of Gauteng punches way above its weight, contributing 33% to the national economy and a phenomenal 10% to the GDP of the entire African continent.

The name Gauteng means 'place of Gold' in Sesotho – Sesotho being one of the 11 official languages in South Africa. The Province was built on the wealth of gold found deep underground – 40% of the world's reserves. With gold mining no longer the economic mainstay, the economy has since diversified with more sophisticated sectors, such as finance and manufacturing, setting up shop. Gauteng is essentially one big city, with 97% of its population living in urban centers from Pretoria to Johannesburg. Pretoria is the political capital of South Africa, while Johannesburg is the economic capital – and by far the biggest city in South Africa and Africa as a whole. The latter is also known as Jo-burg or Jozi, and is often compared to Los Angeles – with its similar urban sprawl, linked by huge highway interchanges. Johannesburg is a single municipality that covers over 1,645 km^2 – by comparison, Sydney, Australia's central municipality, covers 1,500 km^2.

FREEWAY UPGRADE PROJECT

We were awarded the contract for post-tensioning and incremental launching services on three bridges which form

“A PARTICULAR CHALLENGE WITH THESE TWO BRIDGES IS THAT THEY HAVE AN AVERAGE DOWNHILL SLOPE OF 4%, WITH LAUNCHING DONE IN THE DOWNHILL DIRECTION.”

part of the Gauteng Freeway Upgrade project – and this was the first major contract secured by the Structural Systems Group in Africa.
This major upgrade project was tendered in different packages. Package E was won by the Siyavaya Highway Construction JV – a joint venture between Group 5 Civil Engineering, Liviero, Power, Bophelong and Umso Construction. It contains three incrementally launched bridges on the N12/N17 highway intersection and at the N3/N12 Elands Interchange in Johannesburg.

BRIDGES ONE AND TWO

Two of the bridges are 150 m long, 10-segment straight bridges, crossing four piers with a maximum deck span of 26 m, constructed on either side of an existing bridge on the N12 highway where it crosses the N17 Highway. The purpose of the two new bridges is to give northbound traffic on the N12 highway direct access to the N3 and N17 highways respectively.

DOWNHILL SLOPE

A lift and push launching system, located on the bridge abutment, was used for the bridge launching. A particular challenge with these two bridges is that they have an average downhill slope of 4%, with launching done in the downhill direction. This required Structural Systems Africa to use a combination of brake systems to restrain the bridge during and between launching of the bridge, consisting of a steel brake saddle with gripper plates for increased friction between the underside of the bridge deck and the brake saddle, located at the abutment in front of the launching system, and a hydraulic brake system located at the back of the cast bed, using a pair of hydraulic restraining jacks connected to the back of the bridge deck with stress bars to restrain the bridge during launching. →

Technical insight: Incremental launching

Incremental launching is a bridge construction method particularly suited to the construction of continuous PT multi-span bridge structures. This method has been successfully applied by BBR Network Members for dozens of bridges in Europe, Asia Pacific and other parts of the world.
Construction for incrementally launched segmental bridges involves manufacturing bridge superstructure segments in a fabrication area, set up behind one of the abutments. A new segment is match-cast against the preceding segment and after curing, the whole superstructure is moved forward by the length of one segment. The superstructure is launched over temporary sliding bearings on the piers. To keep the bending moment low in the superstructure during construction, a launching nose is attached to the front of the bridge deck.
Launched segmental bridges combine the advantages of cast-in-place and precast bridge construction. The construction method is environment friendly, as it does not interfere with the landscape it passes over and the casting yard requires only minimum space. Furthermore, the superstructure can be produced to the highest quality and safety standards in the casting yard, which can easily be sheltered for continuous production. Launching equipment is inexpensive compared to other bridge construction methods and consists mainly of a launching nose, thrust system and a casting cell.
The launching technique is normally used for straight bridges or curved bridges with constant radius, and is generally economical for medium spans ranging from 30 to 60 m. The most suitable cross-section is the single cell box section. Due to alternating bending moments at almost every section during launching, two types of PT tendons are provided – launch and final tendons.
The two commonly used launching systems are pulling launching and friction launching. The pulling system uses PT strands and jacks to tow the superstructure. Launching speed ranges between 3 and 6 m per hour. Incremental launching is one of the most industrialized and effective forms of construction with potential for expansion in the future.

The back restraint jacks were preset between launches with the force required to restrain the bridge's self-weight only, with minimal friction assumed between the bridge deck, the cast bed and temporary bearings. As soon as the required launch jacking force was then applied by the bridge launching system, the restraint force in the pair of restraint jacks was overcome by the combined force of the bridge self-weight and the launching forces applied by the launching system – and the bridge could be launched forward. As soon as the launching force is not applied, during re-setting of the launching jacks, the brake saddle and back brake jacks restrains the bridge deck against further movement.

The downhill slope also required the use of a series brake 'pins' for restraining the bridge between launch cycles. The 'pins' connected the back of the bridge to the front of the cast bed to prevent the bridges from sliding forward uncontrolled under its self-weight. The bridge design engineers also insisted on restraining the bridge at this location as they felt there was a risk of movement in the bridge deck between the abutment and cast bed due to thermal effects, as the cast bed was located about 35 m behind the abutment.

BRIDGE THREE

The third bridge, on the N3 highway's Elands Interchange, is a horizontally curved bridge

with a total length of approximately 400 m, crossing 10 piers with a maximum deck span of 36 m. The bridge is a single lane bridge adjacent to an existing, curved, three-lane bridge. The new bridge had to be constructed as the number of lanes on the N3 highway was increased from three to four. The existing bridge could not be widened to accommodate four lanes, which required the construction of a new single lane bridge adjacent to the existing to cater for the additional lane of traffic.

A lift and push system, located on the bridge abutment, was again used on this bridge for the bridge launching. Due to the abutment, temporary piers and casting bed being located on 20 m deep engineered fill, the cast bed and temporary piers had to be founded on 12 1.2 m diameter in-situ bored piles. The abutment was not designed for any lateral launching forces, and therefore all launch forces had to be transferred to the cast bed through two thrust beams connecting the abutment to the cast bed in line with the launching jacks and cast bed spline beams.

SKILLING UP LOCALLY

Lack of local skills was a major obstacle faced by the newly-formed Structural Systems Africa office. This was overcome with support given

by the Structural Systems group who sent one of its most experienced Australian supervisors from the Perth office to assist with the pre-launch site set-up and training of local crews in the techniques of PT installation and incremental bridge launching.
This approach of on-the-job training was highly effective, as Structural Systems Africa's local crew has now seen through the completion of the first 150 m long straight bridge, including the permanent bearing installations. The second 150 m long straight bridge was well on track with five launches completed by early August 2010 and the bridge was completed in November 2010. The first launch for the 400 m long Elands Bridge was completed at the end of July 2010 and the bridge is due for completion in July 2011.

WARM WELCOME FOR BBR

This project is only the second major project in Southern Africa to make use of the BBR VT CONA CMI multi-strand anchor system.

Although it is not the first time BBR stressing technology has been used in South Africa, the re-introduction of the latest BBR VT CONA CMI stressing technology into South Africa by Structural Systems Africa has been widely welcomed by contractors and engineers alike.

NEW BRIDGE FOR LAUNCHING

Due to the good progress and experience gained on this project, the Structural Systems Africa office has also been awarded the contract for providing the same services on another curved incrementally launched bridge in the province of Kwa-Zulu Natal, which will be the fourth such bridge involving Structural Systems Africa and BBR Technology in the space of 2½ years. Structural Systems Africa, the Structural Systems Group and BBR VT International are proud to be involved in this project and look forward to more exiting projects in Southern Africa, and to play a part in the building of South Africa and Africa and also sharing the African Renaissance vision of Mr Nelson Mandela, which is to make South Africa and Africa a better place for all – a vision shared by South Africans of all races and backgrounds.

TEAM & TECHNOLOGY

OWNER South African National Roads Agency Limited (SANRAL)

MAIN CONTRACTOR
SIYAVAYA Highway Construction JV

CONSULTANTS
Nyeleti / UWP Consulting JV & Knight Piesold / Arcuss Gibb / Siyenza Consulting JV

TECHNOLOGY
BBR VT CONA CMI internal
Launching

BBR NETWORK MEMBER
Structural Systems (Africa)

Crowning glory

A7 HIGHWAY GUADALFEO VIADUCT, SPAIN

The Lobres-Guadalfeo section of the A7 highway is set in a breathtaking landscape between Salobreña, a major tourist destination on the sun-soaked coast of south-eastern Spain and the slopes of the Sierra Nevada ski station – one of Europe's highest sun-and-snow winter sports resorts. This area is unique as it is the only part of the Mediterranean coast which is not connected by a fast road. The scenic location of the new highway connections means that its route features several tunnels, viaducts, flyovers and bridges. The different techniques, employed on this new challenge are described by José Luis Plaza of BBR PTE.

Our extensive scope of works and wide range of products and services was key to our appointment to collaborate and undertake the overall project – which has two flyovers and one viaduct over the River Guadalfeo.

GUADALFEO VIADUCT

The viaduct is divided into three independent spans across a total length of 280 m. The central 140 m long span is supported by an arch, located in the axis of the deck, which is connected to the concrete box upper deck by 15 hangers and side spans of 34 + 36 m each. The side spans are connected to the central span with 18 1,030 N/mm^2 PT bars.

The viaduct is a 10 m wide concrete box section. Cantilever precast segments were placed to widen the viaduct to a total width of 25 m. The post-tensioning tendons consist of 31 15.7 mm diameter strands utilizing BBR VT CONA CMI anchorage systems.

Only towards the end of construction was the Guadalfeo Viaduct, which crosses the river and the N-323 road, crowned with its striking ornamental arch.

CONSTRUCTION PROCESS

The central span of the viaduct was concreted in three phases using conventional formwork. This span was supported over three temporary piers. The composite arch, consisting of a concrete-filled steel box, was anchored to the deck with 12 40 mm diameter PT bars. The bars were stressed before the hangers were placed in their position. Fifteen steel tube hangers are joined to the arch with a pin-open socket and to the deck by six 50 mm diameter bars per hanger.

STRESSING OPERATION

The hangers were stressed symmetrically to the arch axis. Two jacks were placed in the central bars of the lower steel anchorage and first stage simultaneous stressing took place. The difference in temperature recorded between the arch, deck and hangers produces such a variation in force, as regards the neutral state in the hangers, that it is necessary to take this into account during the stressing process, so that the loads applied to the hangers match the theoretical force after stressing.

“TO RECORD THE FORCE EXERTED ON THE HANGERS, JACKS WERE PROVIDED WITH CALIBRATED GAUGES.”

To record the force exerted on the hangers, jacks were provided with calibrated gauges. In addition, load cells and extensiometric strips were placed to give an independent check on the accuracy of the gauges.
After all the central hanger bars were stressed, the clearance gaps between the lower anchorage of the hangers and upper slab concrete box were filled with grout. Finally, all the hanger bars were re-stressed until the final force was achieved. All bars were protected against corrosion by a layer of cement grout injected into the ducts to encase the bars
Once all hangers were re-stressed and grouted, the three temporary piers under the central span were removed. Four hydraulic jacks were installed on each pier to lift the deck and remove the temporary neoprene bearings.

FLYOVERS

In addition, two small structures were executed using BBR VT CONA CMI internal tendons. We installed 12 steel tendons made up of 31 strands of 15.2 mm prestressing steel for each flyover. We used 750 t capacity hydraulic jacks for stressing the tendons.

TEAM & TECHNOLOGY

OWNER Ministerio de Fomento
MAIN CONTRACTOR FCC Construcción
DESIGNER FCC Technical Services
TECHNOLOGY BBR VT CONA CMI internal
PT bar
Hanger
BBR NETWORK MEMBER BBR PTE, S.L. (Spain)

Photograph courtesy of Per Frode Bu, www.bugard.no, perbu@eidfjord.net

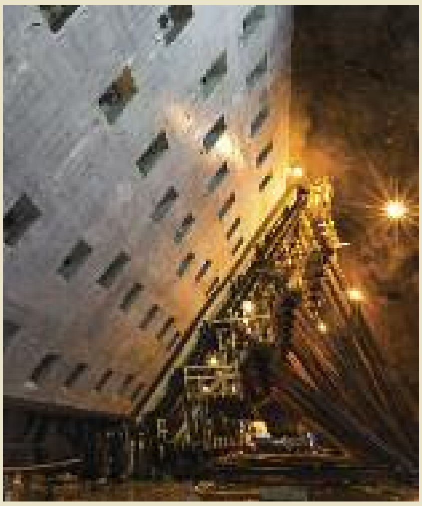
HARDANGER BRIDGE, NORWAY

Prestressing progress

It’s full speed ahead with post-tensioning work on the Hardanger Bridge, reports Stig Solbjør of Norwegian BBR Network Member Spennteknikk.

The famous Hardangerfjord is the third longest fjord in the world and the second longest in Norway, however, crossing the fjord to get around the local area requires a journey by ferry. As well as rivaling other great bridges – such as San Francisco’s Golden Gate Bridge – when it opens in 2013, the new bridge will improve commuter routes and generally shorten journey times in the region.
The bridge design features two towers – one on either side of the fjord – and these will be anchored to the rock. As the tower foundation area is very steep, the main contractor wanted to reduce the extent of the foundations – consequently, the quantity of rock anchors increased. From an original requirement for 32 anchors, with the new foundations the number has now increased to 52 – all of which were installed in October 2010. The two 200 m towers have now started to grow and it is anticipated that both will be completed during the winter of 2011.
The massive chambers for anchoring the suspension cables are ready and the prestressing work on the north side of the fjord was finished in 2010. The cables are placed in individually drilled holes from the upper anchor zone down to a tunnel where they are anchored by 76 BBR VT CONA CMI 2506 tendons on each side. The prestressing work is being carried out from the lower end, inside the tunnel rather than in the anchor zone, due to the limited anchor head access. Construction started in May 2009 and the new Hardanger Bridge is scheduled to open in 2013.

Photograph courtesy of Per Frode Bu, www.bugard.no, perbu@eidfjord.net



TEAM & TECHNOLOGY

OWNER Statens Vegvesen
MAIN CONTRACTOR
Veidekke Entreprenør AS
DESIGNER
Statens Vegvesen, Norconsult AS and Rambøll AS
TECHNOLOGY
BBR VT CONA CMI internal
BBR CONA ground anchor
BBR VT TOBE pot bearing
BBR NETWORK MEMBER
KB Spennteknikk AS (Norway)

Metro magic

The Delhi Metro Rail Bridge at Dhaula Kuan is India's longest span metro rail bridge with twin tracks. Mr. K. P. Suseelan, Regional Project Manager of BBR (India) Pvt Ltd, the BBR Network Member in India, reports on the construction of the bridge deck and of BBR's involvement in the project.

The new bridge for the metro rail system stretches over one of Delhi's busiest traffic intersections, at Dhaula Kuan. This bridge forms part of the connection between Delhi Airport and New Delhi Railway Station. This section was specifically designed as a five-span continuous structure to minimize obstruction – by support piers – of the road running beneath. It has high spans of 71 m, 93 m, 96 m, 114 m and 168 m. Our scope of work included post-tensioning for which we used the BBR CONA internal system.

BRIDGE OVERVIEW

The 542 m long viaduct for the Airport Metro line has a maximum span of 168 m. It is post-tensioned with 3706 BBR CONA tendons – representing the heaviest and longest single length post-tensioning tendons used on the metro bridges. There are 15 tendons in the longest viaduct span.

VIADUCT CASTING

There were five typical spans and, of these, the 168 m span is the longest one ever constructed for a metro rail project in India. The viaduct was cast-in-situ. The shuttering and reinforcement was carried out over heavy-duty centering with structural steel fabrication, to ensure the necessary safe and clear overhead working environment, without disturbing road traffic passing beneath the construction works. HDPE corrugated sheathing was provided, for both external and internal tendons, and this consisted of 156 mm external and 138 mm internal diameter ducts. The strands in each duct were threaded using a mechanical threading machine. The strand threading operation was completed before the viaduct was concreted.

STRESSING AND GROUTING

After the structure had attained the required concrete strength, the cables were stressed in sequence. We used a special heavy duty BBR 1,000 t jack with a 200 mm ram stroke length – from our own fleet of equipment. The stressing was carried out simultaneously on either side of the viaduct. Once the stressing was completed and, following a slippage check 24 hours later, the strands were cut and the ducts were filled with cement grout. ●

TEAM & TECHNOLOGY

OWNER Delhi Metro Rail Corporation (DMRC)
MAIN CONTRACTOR M/S. Tantia Constructions Limited
DESIGN/SUPERVISION M/S. Systra Consultants
TECHNOLOGY BBR CONA internal BBR CONA external
BBR NETWORK MEMBER BBR (India) Pvt Ltd

Crossing the Tisza

The M43 highway between Szeged and Makò diverges from the M5 north-south motorway north-west of Szeged. The most interesting part of the new highway – that can later be developed into a motorway – is the crossing of the River Tisza and the flood area with three bridges which have a combined length of 661.2 m.

The main bridge, consisting of two 96 m side spans and a 180 m main span. Austrian BBR Network Member **Vorspann-Technik** was contracted to deliver the BBR VT CONA CMB band post-tensioning system and stressing equipment and, after a flood caused delay for several months during spring and summer, the bands were mounted and stressed last autumn. ●

TEAM & TECHNOLOGY

OWNER Nemzeti Infrastrutúra Fejlesztö Co.
MAIN CONTRACTOR Hídepitö Zrt
DESIGNER (RIVER BRIDGE) Pont-TERVCo
TECHNOLOGY BBR VT CONA CMB band
BBR NETWORK MEMBER VORSPANN-TECHNIK GmbH (Austria)

WAIKATO RIVER BRIDGE, TAUPO, NEW ZEALAND

Relieving PRESSURE

Lake Taupo is New Zealand's largest lake covering more than 600 km² and is the heart of the North Island. The lake was created by a huge volcanic eruption several thousand years ago and the region still contains live volcanoes, geothermal fields, boiling mud pools and steaming geysers. Taupo itself is a resort town and sits right on the lakefront – with the main state highway network running right though the centre of the town. Lake Taupo is a very popular tourist destination in both summer and winter. Keith Snow, Northern Regional Manager for New Zealand-based BBR Contech, reports that a new NZ$110 m road bypass is being constructed to reduce the number of heavy vehicles running through the township and along the lakefront and to ease traffic congestion during holiday season and events.

The new 16 km East Taupo Arterial route is being constructed by main contractor Fulton Hogan and involves a series of new bridges, one of which is a 100 m network arch bridge spanning across the Waikato River. Network arch bridges are generally of relatively light construction and are typically constructed close to the final location and lifted into position. They are ideally suited to sensitive environments or where there are access restrictions. The Waikato River Bridge features 76 'hangers' of 64 mm, galvanized steel bar. Strung between the deck and a 50 t arch structure, the Grade 460 hangers provide essential support for the new bridge. We supplied the hangers, complete with forks and pins, to steelwork subcontractor Tenix who installed them for main contractor Fulton Hogan.

In a unique construction sequence designed by Fulton Hogan, the lower chords of the bridge deck were launched into position first and seated on temporary supports – across a narrow stretch of river close to the final location. The main arch members were then craned into position and the arch hangers were installed one-by-one. The whole bridge was then lifted into its final position by cranes positioned on each side of the river – an impressive feat considering the entire steel arch structure – excluding land spans at either end – weighs 400 t.

The deck of the bridge also contains longitudinal post-tensioning – designed to resist the horizontal forces created by the arch action and to provide additional flexural capacity. There was a total of 12 tendons through the deck – eight BBR CONA 1205 and four BBR CONA 705. The 100 m long tendons were stressed and grouted near the end of the bridge construction process, following the construction of the concrete deck slab.

The project was completed three months ahead of schedule and was opened in October 2010.

TEAM & TECHNOLOGY

OWNER
NZ Transport Agency / Taupo District Council

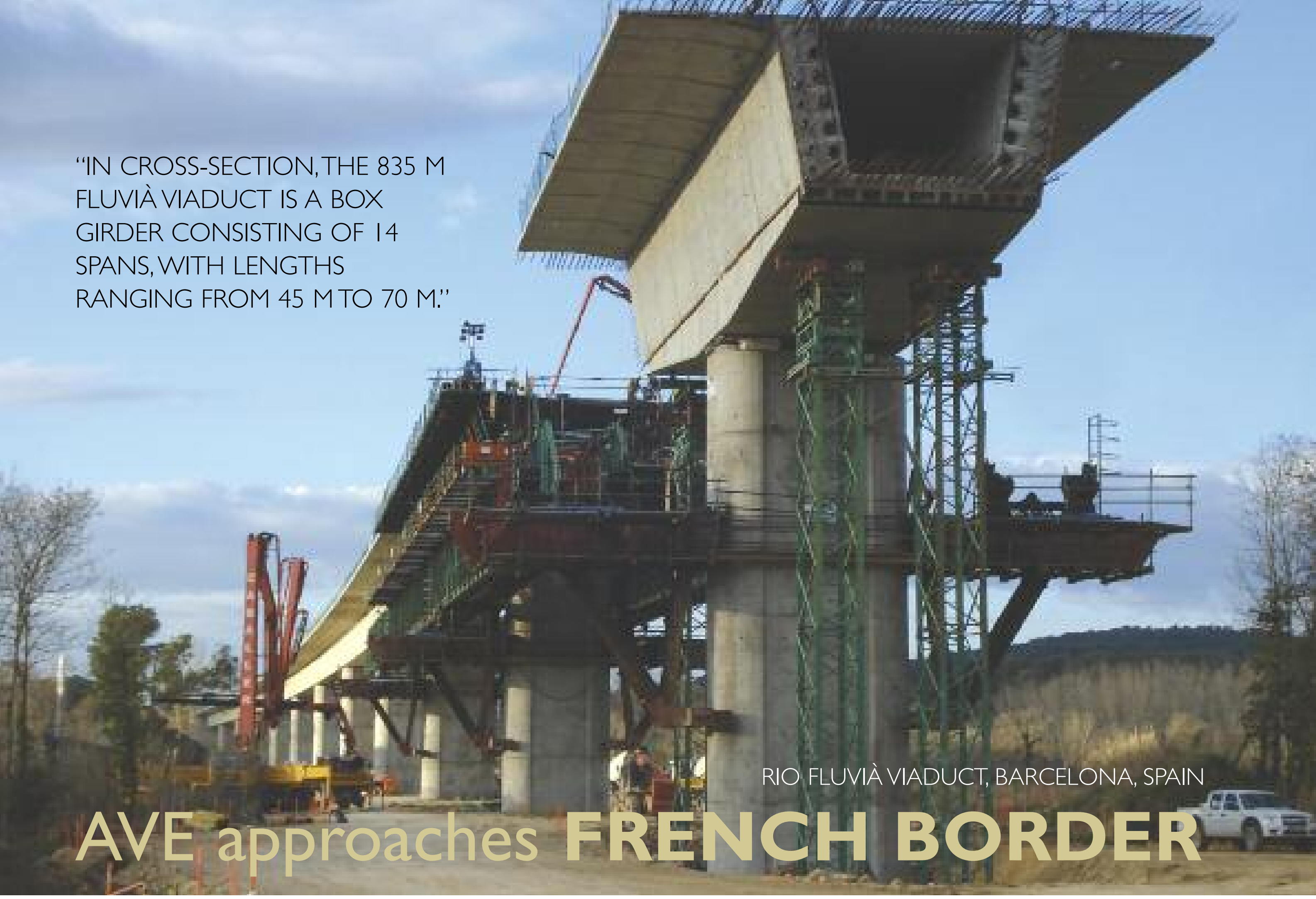
MAIN CONTRACTOR Fulton Hogan

DESIGNER Holmes Consulting Group

STEELWORK CONTRACTOR Tenix

TECHNOLOGY BBR CONA internal Hanger bar

BBR NETWORK MEMBER
BBR Contech (New Zealand)



RIO FLUVIÀ VIADUCT, BARCELONA, SPAIN

AVE approaches **FRENCH BORDER**

"IN CROSS-SECTION, THE 835 M FLUVIÀ VIADUCT IS A BOX GIRDER CONSISTING OF 14 SPANS, WITH LENGTHS RANGING FROM 45 M TO 70 M."

At 835 m long, the Rio Fluvià Viaduct, is the longest viaduct to be constructed on the Barcelona-Figueres section of Alta Velocidad España's line from Barcelona to the French border. It is one of the noteworthy structures on the 5.7 km Vilademuls-Pontós section of the route. José Luis Plaza Bacete of BBR PTE, in Spain, reports that, as well as the Rio Fluvià Viaduct, another three viaducts have been constructed to complete this project.

The post-tensioning for these viaducts was developed thanks to collaboration between BBR PTE (Spain) and the designer Bridge Technologies.
The method selected for the Rio Fluvià Viaduct was span-by-span construction using auto-launching girders. Work began with the installation of the auxiliary structures by means of which the deck is constructed 'in situ'. These launching girders supported the complete 22,000 t weight of the deck during the works and allowed installation of reinforcement, concreting and stressing in sections of up to 70 m long. The construction method minimized disruption to the road traffic and no road diversions were necessary. A moveable scaffolding system was used for the other three viaducts where construction was based on full span cast-in-situ techniques.

FLUVIÀ VIADUCT

In cross-section, the 835 m Fluvià Viaduct is a box girder consisting of 14 spans, with lengths ranging from 45 m to 70 m. The single cell box girder is 4 m high and the top slab is 14 m wide. It has a tracing curve with a radius of 6,000 m.
All tendons were designed as internal, 140 and 150 mm^2, using the BBR VT CONA CMI post-tensioning system.
In order to improve the distribution of the post-tensioning forces, ten tendons with 31 strands and stressing anchorages in both ends were used for the longitudinal tendons running along the webs of the box. The tendon layout crosses in areas where there are construction joints to avoid the need to place couplers in those sections. The concentration of tendons in this zone of the box is greater than normal, as the web thickness had to be increased to permit the installation of bearing trumplates, trumpet, reinforcement in the anchorage zone – and the tendon layout had to be designed to provide a sufficient straight length beyond the end of the trumpet. This is one of the main characteristics of this viaduct.
The post-tensioning force was introduced in two stages. The first stage was when the bottom slabs and webs had been concreted, only the six tendons located in the lower part of each web could be stressed.
In the second stage, when the upper slab of the deck had been concreted, we were able to stress the remaining tendons which had

not previously been stressed.
To allow restressing of the tendons, it was necessary to design a steel girder that could be fixed to the upper slab of the deck. The hydraulic jack could be moved along this girder to ease correct positioning of the jack in each anchor head. The dimensions of the anchorage recesses and the inclination of tendons had to be adapted to place the prestressing jacks perfectly perpendicular to the axis of the tendons. In addition, to absorb negative moments, we placed eight tendons of 12 strands in the upper slab over piers – and, in the middle of spans 12 and 13, eight tendons with 19 strands.
We used a total of 350 t of steel.

CINYANA VIADUCT

This viaduct is a concrete lightened slab deck. It has an overall length of 85 m, with only one span between abutments. Here, we used a moveable scaffolding system for full span cast in-situ construction. The viaduct has 12 BBR VT CONA CMI 3106 tendons with stressing anchorages at both ends – approximately 30 t of 15.2 mm post-tensioning steel was used.

CASINYOLA 1 & 2 VIADUCTS

These viaducts are also concrete lightened slab decks and we employed the same method as for the Cinyana viaduct. We used a total of 70 t of 15.2 mm post-tensioning steel for the two viaducts.
Casinyola 1 has 10 BBR VT CONA CMI 3106 tendons with stressing anchorages at both ends. It is 126 m long, with an intermediate construction joint with couplers and anchor heads.
The 78 m long Casinyola 2 viaduct also has ten BBR VT CONA CMI 3106 tendons with stressing anchorages at both ends.
To counteract the braking forces of high speed trains, we installed special PT tendons with adjustable anchorages to join the abutments to the decks on all the viaducts.
Last winter, we had record-breaking bad weather where we were working, near the Pyrenees, in northern Spain. Despite the problems this caused, as usual, we completed the project within the client's program. ●

TEAM & TECHNOLOGY
OWNER ADIF
MAIN CONTRACTOR JV FCC + Serviá Canto
DESIGNER Bridge Technologies
TECHNOLOGY
BBR VT CONA CMI internal
Advanced shoring
BBR NETWORK MEMBER BBR PTE, S.L. (Spain)


KUFA BRIDGE, IRAQ

Bridging the Euphrates

The new bridge over the Euphrates River, near the town of Kufa, now links both river banks and provides an additional access to the holy town of Najafa. Safwan Al-Ani of Specialized Prestressing Co, the BBR Network Member in Iraq, reports on the role his company played in the creation of this new link.

The BBR CONA internal post-tensioning system was chosen for this 350 m long ten-span bridge. Each span segment was 35 m long and the overall width of the bridge was 15 m.
Our task on this project was to construct the precast post-tensioned girders in the casting yard on site. Work including cutting, bending and installing the reinforcement bars, as well as providing and fixing the post-tensioning system, closing the formwork, concreting the girders, two-stage stressing of the tendons and grouting. We prepared the calculations for the expected elongation and shop drawings, with additional support from BBR Construction Systems (M) in Malaysia.
The bridge is now open for traffic and was welcomed by the local community. ●

TEAM & TECHNOLOGY
OWNER
State Corporation for Roads and Bridges
MAIN CONTRACTOR
Abdullah A. Al-Jiburi Contracting Company
TECHNOLOGY BBR CONA internal
BBR NETWORK MEMBER
Specialized Prestressing Co (Iraq)

RACING AHEAD

NAD AL SHEBA BRIDGES, DUBAI, UAE

Ravindra Kumar Chauhan, Civil Operations Manager of Dubai-based BBR Network Member, NASA Structural Systems LLC, reports on their project for the post-tensioning of three bridges which are part of the high-profile Nad Al Sheba Race Course Development.

The Nad Al Sheba Race Course Development is one of the prestigious projects being undertaken by the Government of Dubai and consists of the construction and development of a race course, stadium and a dedicated road and bridge network to provide easy access to the race course.

The Dubai Roads & Transport Authority appointed Afcons Construction Mideast LLC as main contractor for the project which consists of three bridges – the Main Bridge, Bridge MDN-1A and Bridge MDN-3D. In turn, Afcons subcontracted the specialist post-tensioning works for these three bridges to NASA Structural Systems LLC. We used the BBR VT CONA CMI 1206, 1906, 2406 and 3106 anchorage systems for this project which required 700 t of prestressing steel.

PROJECT OVERVIEW

The six-lane Main Bridge is comprised of four single cell boxes with a common deck slab, forming a total bridge length of 440 m divided into 11 spans, ranging from 32 m to 60 m long. Bridges MDN-1A and MDN-3D, however, are each to carry two lanes of traffic only and are comprised of twin cell box girders with a total of eight spans ranging from 32 m to 55 m long. The MDN Bridges 1A and 3D are 329 m and 200 m long, respectively. Tendon couplers were utilized to sub-divide the construction of the three bridges into a total of 11 stages – with the longest prestressing tendons measuring an impressive 148 m.

SOLVING SPACE REQUIREMENTS

Consulting engineer Africon's original design called for installation of three tendons with 34 or 48 15.7 mm strands for each web of the Main Bridge and Bridge MDN-3D, but due to height restrictions and centre-to-centre spacing requirements, it was not possible to set the higher capacity anchorages as detailed.

We proposed a solution involving splitting each of the 34 and 48 strand tendons in two tendons of 17 and 24 strands, respectively – resulting in six tendons of 17 (and 24) strands, with two parallel tendons running through the webs without any change in design. This proposal was accepted by Africon – as it solved the inherent problems in a timely fashion, without the need for redesign – and allowed us to use BBR VT CONA CMI 1906 (with 17 strands) and 2406 anchorages without modifications to the original concrete sections.

BLISTERING SOLUTION

The consulting engineer's requirement for the Bridge MDN-1A tendon couplers to be staggered, to avoid having all couplers in a single plane, resulted in the number of construction joints being doubled and the construction schedule was thus expected to be delayed. The main contractor approached us for a solution to avoid the additional construction joints, which had solely been introduced to stagger the couplers. We proposed that – out of three BBR VT CONA CMI 3106 tendons in a web – two could be coupled in one plane, with the third one to be overlapped by introducing an anchorage blister in the webs. The proposal was accepted by the consulting engineer and the additional blister we introduced enabled the main contractor to race ahead and hand over the project on time.

TEAM & TECHNOLOGY

OWNER Roads & Transport Authority

MAIN CONTRACTOR
Afcons Construction Mideast LLC
Consultant Africon (now known as 'Aurecon')

TECHNOLOGY
BBR VT CONA CMI internal

BBR NETWORK MEMBER NASA
Structural Systems LLC (United Arab Emirates)

FOOTBRIDGE, KRAKOW, POLAND

Reconnecting the river banks

Bartosz Łukijaniuk and Pawel Surman of BBR Polska recounts that during the summer of 2010, the company took part in an interesting project – a foot-bicycle bridge over the River Vistula in the historic city of Krakow which was the capital of Poland between the 11th and 16th centuries.

TEAM & TECHNOLOGY

OWNER ZIKiT Kraków

MAIN CONTRACTOR Intercor Sp. z o.o.

DESIGNER
PROMOST CONSULTING Sp. z o.o. in cooperation with KBP Piotr Zółtowski and ZB-P Mosty-Wrocław S.C.; architectural design Autorska Pracownia Projektowo-Plastyczna prof. Andrzeja Gettera

TECHNOLOGY
BBR VT CONA CME external
Rotation
Incremental launching

BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

The new foot-bicycle bridge joins two districts – Kazimierz and Podgórze – where, until the 1930s, the Franz Josef bridge had connected the river banks. The new bridge is the first investment of this kind in Krakow and will make boulevards along river banks more attractive to visitors.

CURVED DECKS

The structure consists of two curved decks – one for pedestrians and one for cyclists – supported on steel crossbeams suspended with steel bars from a steel arch. The span of the arch is almost 146 m, the height is around 14 m and the total length is approximately 172 m. The arch is tied with BBR VT CONA CME external tendons.

ROTATION METHOD

The bridge was executed by the rotation method. The arch with suspended crossbeams and decks was prepared on temporary supports along the river banks. After partial tensioning, the structure was launched on barges from where the bridge was rotated to its final position. After final tensioning, completed after the rotating process, the structure was tied to the abutments.

PERFECT CO-OPERATION

During such a relatively small – but unique – project, it is essential that there is a great spirit of cooperation between all those involved. We enjoyed a perfect working relationship with the very well-organized general contractor – Intercor Sp. z o.o. (conducted by Piotr Jurczyk and Zdzislaw Pietek) – right from the earliest stages of the contract, and this ensured that the realization went smoothly. The foot-bicycle bridge in Krakow is just one of many contracts around Poland that BBR Polska has carried out together with the Intercor team.

VITAL **LINK**

RIVER EBRO BRIDGE, TARRAGONA, SPAIN

In north-eastern Spain – in Tarragona, Cataluña to be precise – there is a fabulous bridge which has joined two villages previously separated by the River Ebro. The only connection between the villages of Deltebre and Sant Jaume d'Enveja had been a ferry which made the same journey countless times every day. David Olivares Latorre, of Spanish BBR Network Member BBR PTE, reports that there were tears in the eyes of elderly people when, in June 2010, they lifted the central span into place. From this moment, the dreams of thousands of people became reality.

The bridge is divided into three spans – two side spans joining the shores and a central span. The project included four massive 250 m long 73-strand BBR VT CONA CME external tendons enclosed in 225 mm diameter external black HDPE pipes. Our preparation work included assembling the CONA CME external stressing anchorages, the preparation and installation of all HDPE pipes before the lifting operation for the central span which sat on the riverbank during construction.

LIFTING THE CENTRAL SPAN

The central span was lifted from the shore by two spectacular cranes and placed in the River Ebro. Tug boats guided the 540 t structure across the water into the correct position. We then connected the four 230 t hydraulic heavy lifting jacks – fixed on two auxiliary steel structures at the top of either side of the bridge – to the central span with four 19-strand tendons. With a team of four professionals and engineers, it took only six hours to complete the synchronized heavy lifting operation.

STRESSING OF EXTERNAL TENDONS

After lifting, the four 73-strand external tendons were inserted through the HDPE pipes. We used two hydraulic strand pushing machines for this task. After the top slab had been concreted, the four tendons were stressed using four 1,250 t hydraulic jacks working simultaneously in pairs – two jacks at each side of the tendon.

CORROSION PROTECTION

The final step was the correct corrosion protection of the tendons. We decided to use a special thixotropic grout to the specifications stipulated in ETAG 013, combined with a specific grouting method. Each tendon was equipped with a protection cap and four vents on the highest points, next to the pylons. The entire grouting procedure was carried out in three stages, using a peristaltic pump and by creating a vacuum inside the pipes. First, the central span was grouted without filling the top of the two pylons. The second step was to fill both extreme sides of the tendons with grout – and the final step was to insert the grout at the top of the pylons.

TEAM & TECHNOLOGY

OWNER GISA – Generalitat de Catalunya
MAIN CONTRACTOR FCC Construcción S.A.
DESIGNER TEC-4
TECHNOLOGY
BBR VT CONA CME external
Heavy lifting
BBR NETWORK MEMBER BBR PTE, S.L. (Spain)

DIAGONAL ZERO ZERO TOWER, BARCELONA, SPAIN

Diagonal Diamond

Close collaboration between the designer and BBR PTE ensured all specialist construction details were considered and that this awe-inspiring skyscraper was finished on time – demonstrating again the benefits of using BBR post-tensioning systems.

Located at the beginning of the Avenida Diagonal, which divides the city of Barcelona in two from West to East, the Diagonal Zero Zero tower stands proud on the city skyline and right in its most fashionable district. The 110 m office tower has 24 floors, with a diamond shape and glass façade, designed by the Catalan architect Enric Massip-Bosch. When completed, it will provide space for more than 1,500 people and parking for 350 cars. The building is built according to strict criteria and features bioclimatic energy use. Post-tensioned structures not only reduce environmental impact, but their correct use also saves money by reducing material quantities and increasing construction speed. The supports to the diamond shaped skyscraper consist of only a central core and perimeter columns. A post-tensioned solution was chosen and we used the BBR CONA flat 0406 and 0506, along with BBR VT CONA CMI internal systems, comprising up to five 15.2 mm diameter high yield strands inside a flat and circular steel duct. Post-tensioned tendons were located in some deep border ribbed beams and others were distributed across 30 cm thick ribbed reinforced concrete slabs. After stressing, the ducts were injected with cement grout to provide bond and corrosion protection ●

TEAM & TECHNOLOGY

OWNER El Consorci Zona Franca Barcelona

MAIN CONTRACTOR FCC Construcción

DESIGNER MC2, Estudio de Ingeniería

TECHNOLOGY
BBR VT CONA CMI internal
BBR CONA flat

BBR NETWORK MEMBER BBR PTE, S.L. (Spain)

Triumph FOR JUSTICE

LAS PALMAS COURT BUILDING, CANARY ISLANDS, SPAIN

The location of the law courts on many different sites around the capital of Gran Canaria creates confusion and inconvenience, both to professionals and to the general public. Today, there are 16 different seats of justice. To improve this situation, the new City of Justice, already under construction, will house all the courts of Las Palmas de Gran Canaria. José Luis Plaza, from BBR PTE in Spain, reports on the largest and most complex post-tensioning project ever undertaken in the Canary Islands.

The new City of Justice will be built on an area of over 12,000 m^2. Below ground are two basements with a total built area of 24,900 m^2 which will house cells and provide 280 parking spaces, as well as storage of exhibits and documentation. The floor area reduces at ground level and for the first and second floors where the area is around 7,200 m^2. From the second level, will be four independent towers of differing heights. There is an approximate total area of almost 51,000 m^2 of 30 cm thick post-tensioned slabs on a 10.8 by 10.8 m grid.

The four towers – with heights of eight, nine, seven and ten floors – are being constructed above the second level and will be used by the Social and Administrative, Civil Hearing and Criminal Las Palmas jurisdictions, respectively. The towers will each have a vertical communication system, as the higher bodies are distributed in each jurisdiction, while the three commonly used levels will run horizontally through the entire building.

All the slabs from ground level were executed using the BBR VT CONA CMM monostrand post-tensioning system. Tendon cross-sections are 150 mm^2, with a tensile capacity of 279 kN. We used in excess of 320 t of post-tensioning steel.

Monostrands were prepared and fixed anchorages were prelocked inside a specific zone on the ramps for underground access levels. Then all tendon bands were grouped, each group was craned to the slabs and installed according to the drawings. The arrangement of tendons is such that they are banded in one direction near the columns and distributed in the other principal direction.

Stressing was performed three days after pouring concrete, when the mean concrete compressive strength was 25 MPa. Consequently, formwork costs were reduced – the early removal of formwork resulted in a shorter floor-to-floor cycle time. In addition, slab deflection was minimized because of the compressive forces applied to the structure during prestressing. This reduced risks with the finishing trades and thus ensured long term maintenance costs will be reduced when compared to a conventionally reinforced solution. There was also a significant reduction in the amounts of concrete and reinforcement, so a further saving was achieved in the vertical elements and foundations. BBR PTE has worked closely with the designer BOMA to provide the fully detailed design for construction drawings to ensure that the design and floor configuration meet the specified requirements laid down in the European Technical Approval BBR VT CONA CMM monostrand (ETA – 06/0165). It is envisaged that the City of Justice will be completed in late 2011 and the first cases heard during the second quarter of 2012. Equipping the new facility will also be a challenge – for example, furniture will be needed, along with some 100 km of shelving – and also around 950 staff will be needed, along with 90 clerks and 175 judges and prosecutors. However, the new post-tensioned building will be ready to adapt to any changes, as the new courts and services already represent a capacity increase of some 60% when compared to the old facilities. ●

TEAM & TECHNOLOGY

OWNER Gobierno de Canarias. Consejería de Presidencia y Justicia

MAIN CONTRACTOR FCC Construcción & Santa Ana Cazorla

DESIGNER BOMA

TECHNOLOGY BBR VT CONA CMM monostrand

BBR NETWORK MEMBER BBR PTE, S.L. (Spain)

Local insight: The Canary Islands

THE CANARY ISLANDS are an archipelago off the northwest coast of mainland Africa and are an autonomous community within Spain. While Las Palmas is the capital of Gran Canaria, it shares joint capital status of the Canary Islands as a whole with Tenerife's Santa Cruz.

Under Spanish rule since the early 15th century, both cities became stopping points for galleons on their way to the New World. Consequently, the islands prospered and soon were attracting merchants and adventurers from all over Europe.

According to legend, the Canary Islands – along with the Azores, Madeira and Cape Verde Islands – were once part of the lost city of Atlantis, these islands being the lost continent's highest summits. Somewhat easier to prove is the popularity of the islands today. Some 12 million tourists visit them each year and enjoy their beaches, natural attractions – including the third largest volcano in the world – and sub-tropical climate.

Maximum design flexibility

ARK OFFICE BUILDING, SYDNEY, AUSTRALIA

Structural Systems Limited was awarded the design and construction of over 28,500 m^2 of post-tensioned slabs over 21 floors for Ark – a striking new landmark in North Sydney.

The eye-catching office tower features a unique profile with innovative façades. It has large cantilevered floors at the upper levels facing Mount Street and a stepped western facade integrating external terraces. Large floor plates of up to 2,000 m^2 and the main core being offset ensure maximum design flexibility for tenants.

Incorporating more than 160 t of BBR CONA flat slab post-tensioning, the unique building shape resulted in little similarity between floors and many structural challenges for the design team. This included the incorporation of heavy transfer structures at various levels as well as accommodating the loads from the 'raking' façade columns.

Input from the design team was also critical during the construction phase as the stepped slab edge on each level resulted in conventional methods for support during construction being unsuitable and carefully analyses of the construction loads had to be undertaken. ●

TEAM & TECHNOLOGY

OWNER Investa Property Group
MAIN CONTRACTOR Theiss
DESIGNER Structural Systems Limited
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER
Structural Systems Limited (Australia)

LEVY BUSINESS PARK, ZAMBIA

Paving the way

Structural Systems (Africa) anticipates that the successful completion of its project at Lusaka's new 94,000 m^2 mixed-use project – Levy Business Park – within what is expected to be a relatively short time frame, will pave the way for the use of the bonded BBR PT slab technology throughout South Africa and Africa.

Structural Systems (Africa) has been contracted for the post-tensioning design and site installation of the post-tensioned slabs in the multi-level structured car-park building. The construction will be completed in 18 separate pours, with concrete for the slabs being batched on site by the main contractor. It is anticipated that in the three month contract period, They will install, stress and grout 80 t of 12.9 mm strand.

The use of a post-tensioned flat slab system has eliminated the need for the traditionally reinforced coffer slabs, which are very prevalent throughout Africa. This has ensured significant savings in conventional reinforcement and concrete. ●

TEAM & TECHNOLOGY

OWNER
National Pension Scheme Authority (NAPSA)
MAIN CONTRACTOR Group 5 Building / Zcon Construction Company JV
DESIGNER HBS Africa Consulting Engineers
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER
Structural Systems (Africa)

Back to our roots

MIXED-USE DEVELOPMENTS, AUSTRALIA, INDIA AND BAHRAIN

Jacksons Landing, Sydney

Mid City Centre, 420 George Street

History shows that most human settlements evolved as mixed-use communities where the dwellings people inhabited were multi-functional – serving both domestic and business uses. The density of housing at that time was greater, as the only means of transportation was on foot or by using animals. With the arrival of industrialization and, later mass transportation and the motor car, distances were no longer a problem and people were able to travel further from home for their work or leisure activities. →

In the late 20th Century, urban planners around the world began to embrace and promoted the benefits of mixed-use developments and the synergies they create for modern lifestyles. Among other things, the resurgence of this approach has served to highlight the advantages of using BBR post-tensioning products to preserve design features and to maximize available space. Five current projects are described below – each one benefits from the expertise and technology of the BBR Network.

1

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1 ECONOMIC LONG SPANS AND FAST CONSTRUCTION, CBD SYDNEY

In Australia, two landmark retail and office developments in Sydney's Central Business District are excellent examples of the adaptability of slab system post-tensioning tendons to a wide variety of cast-in-situ concrete floors.

At **Mid City Centre, 420 George Street,** post-tensioning is used throughout the suspended floors which are cast-in-situ concrete. For the repetitive office floors, unusual stepped soffit beams span 15 m clear across the office areas from a central concrete core to perimeter columns providing a highly attractive lettable space. The simplicity and repetition in the structure and 'flying' table forms enabled a fast floor-to-floor cycle.

Darling Walk is predominantly an office building and post-tensioning is also used throughout the cast-in-situ concrete floors. The floors adopt long span band beams – approximately 16 m long, with shallower cantilevers both ends to provide large column free areas. Integral post-tensioned slabs (cast with beams) span about nine meters between these band beams. The same arrangement is adapted for both the rectilinear north and the curved south buildings. Standardization of the structure enabled a high degree of repetition and fast completion of the concrete frame.

2 OPTIMIZING IN BANGALORE

BBR Technology is also being used to realize a seamless open podium floor space in the residential part of one of the leading mixed-use developments in India. The **Prestige Shantiniketan** project in Whitefield, Bangalore has residential and commercial space, including malls, a hotel and convention centre – the total project spreads across a vast area of 4.5 million square feet.

A podium structure – of more than a million square feet in plan area – sits on an elevated slab between the 23 residential towers, each 25 storeys high. There is car parking space in the basement below and a landscaped area on the upper deck.

A post-tensioned waffle slab system was chosen for the elevated podium slab structure, to cater for the large column free space below and high loading on the upper slab level from landscaping materials and vehicular pathways. The loading varies from a minimum of 20 kN/m^2 to a maximum of 35 kN/m^2 – on the upper slab level.

The ribs of the waffle slab feature BBR CONA flat bonded post-tensioning with a 0505 system.

As part of the contract, the design of the post-tensioned podium floor was also carried out by BBR. FRP moulds of waffle units were used and their quantity and the construction sequence were planned to optimize mould usage and minimize impact on the project budget.

4

One of Australia's most prestigious waterfront redevelopments, Jacksons Landing includes commercial office and residential buildings, from low-rise to high-rise towers. Virtually all of the new buildings use post-tensioned concrete floors.
The development is based on the idea of offering a package of houses, apartments, open space and community facilities such as pools, gyms and tennis courts. High density inner-city developments, such this scheme, are seen as one solution to the problem of urban sprawl in Sydney. Upon completion this new estate will house approximately 3,000 residents in 1,339 residential units.

3 RIDING THE WAVE, AMWAJ ISLANDS

On the Amwaj Islands in the Kingdom of Bahrain, a further optimized solution, based on BBR CONA flat post-tensioning has been provided for the construction of the First Wave of the US$ 50 million **Amwaj Waves Phase 1** development.
The development will feature four stunning contemporary residential buildings consisting of two 13 storey and two seven storey buildings and a landscaped pool area, with 1,660 m^2 of commercial space and car parks in the lower podium levels.
The ground, podium, mezzanine and all the tower floors were proposed by the Consultants, MSCEB, to be post-tensioned flat plates to offer an economical solution whereby slab depths and resulting foundation loads are both minimized – and simplified formwork and reduced material quantities can result in speedy construction.
We incorporated bonded BBR CONA flat post-tensioning tendons, typically consisting of either three or five strands, into the PT design and execution to optimize duct and anchorage requirements. Nearly 250 t of post-tensioning strand was required on the 66,000 m^2 of post-tensioned slab.

1

4 EFFICIENCY AND EARLY ACCESS, SOUTH AUSTRALIA

Baju Apartments is a mixed use development situated in Adelaide, South Australia, overlooking the sea at Henley. The building incorporates basement car parking, a retail level and three levels of residential living in 71 apartments. The project utilized 22,000 m^2 of suspended post-tensioned slabs. Our post-tensioned design brief included various dead and live load combinations to facilitate the requirements of the use – and clever detailing was paramount to provide the optimum post-tensioned solution. More than 100 t of 12.7 mm diameter strand was required for the project and we used the CONA flat 0405 and 0505 systems.
Utilizing 40 MPa concrete, an initial stress of 39 kN per strand was applied at minimum concrete strength of 7 MPa (24 hours after pouring concrete) and a final jacking force of 156 kN applied at minimum concrete strength of 22 MPa. Generally, full stressing was carried out 3-4 days after pouring concrete.
Once stressing extensions were approved, strands were cut and tendons grouted, enabling early stripping of formwork, with back-propping remaining. This enabled efficient re-use of formwork to the next level and allowed early access for finishing trades.

5 JACKSONS LANDING, SYDNEY

The **Jacksons Landing** development demonstrates how the BBR CONA flat post-tensioning system can be adapted to virtually any building shape and used in thin suspended flat plate or flat slab floors.
We have provided design and construction advice, as well as supplied, installed, stressed and grouted the post-tensioning for 17 of the building developments comprised within the Jacksons Landing scheme.

TEAMS & TECHNOLOGIES

1 2 3 4 5

TECHNOLOGY BBR CONA flat

1 DARLING WALK, 420 GEORGE STREET, MID CITY CENTRE
OWNER Lend Lease Developments / Fortius Funds Management and Lend Lease Investment Management (APPF)
MAIN CONTRACTOR Bovis Lend Lease
DESIGNER Arup / Taylor Thomson & Whitting
BBR NETWORK MEMBER Structural Systems Limited (Australia)

2 PRESTIGE SHANTINIKETAN
OWNER M/S. Prestige Estates Projects Limited
MAIN CONTRACTOR M/S. IJM India Ltd
ARCHITECT M/S. RSP Architects
STRUCTURAL CONSULTANTS M/S. Potential Service Consultants PVT LTD
BBR NETWORK MEMBER BBR (India) Pvt Ltd

3 AMWAJ WAVES PHASE 1
OWNER OASIS B.S.C. Property Developers
MAIN CONTRACTOR CHAPO Bahrain W.L.L.
CONSULTANT MSCEB, Bahrain
BBR NETWORK MEMBER NASA Structural Systems LLC (United Arab Emirates)

4 BAJU APARTMENTS
OWNER Bayspring Pty Ltd
MAIN CONTRACTOR Hickory Developments Pty Ltd
CONSULTING ENGINEER Robert Bird Group
PT DESIGNER Structural Systems Limited
ARCHITECT Loucas Zahos Architects
BBR NETWORK MEMBER Structural Systems Limited (Australia)

5 JACKSONS LANDING
OWNER Lend Lease
MAIN CONTRACTOR Bovis Lend Lease
BBR NETWORK MEMBER Structural Systems Limited (Australia)

MUSEUM OF TRANSPORT AND TECHNOLOGY, AUCKLAND, NEW ZEALAND

Flying display

Historians and aviation enthusiasts alike will delight in a new development underway at Auckland's Museum of Transport and Technology (MOTAT). BBR Contech Project Manager, Terry Palmer, reports on the post-tensioned floor slab associated with the new building.

Opened to the public in 1964, MOTAT holds more than 300,000 items in its care, including New Zealand's most historic aviation collection. Highlights are the world's only surviving Solent Mark IV Flying Boat, and a World War II Avro Lancaster Bomber, one of only a handful remaining worldwide. With the aim of displaying these superb exhibits at their best, the museum is building a new 'aviation display hall' at its Meola Road site.

The project comprises two stages. The first involves relocating and refurbishing the existing 'Blister Hangar' which was originally built for the Royal New Zealand Air Force during World War II and has since been used for housing aircraft in the MOTAT collection and undertaking aircraft restoration work. The second stage is the construction of a custom-designed building to display the collection. Having completed an extensive design and planning process, BBR Contech will post-tension the foundation floor for the display hall measuring some 40 m by 50 m. The potentially weak ground beneath the building requires that the slab be supported on a network of piles at nominal 5 m centers. The post-tensioned slab design is a collaborative effort between Holmes Consulting and BBR Contech, in conjunction with MSC Consulting. The 250 mm thick slab is designed to span between the piles and cope with about 25 t of concentrated wheel loads from aircraft and other weight. The post-tensioning comprises a combination of BBR CONA flat 0405 and 0305 tendons with a concentration of tendons over the pile lines.

The new aviation display hall will be completed in 2011 and will further enhance the display, character and uniqueness of the MOTAT aviation collection – currently comprising some 40 aircraft. ●

TEAM & TECHNOLOGY

OWNER MOTAT
MAIN CONTRACTOR NZ Strong
DESIGNER Studio Pacific Architecture
STRUCTURAL ENGINEER Holmes Consulting Group/MSC Consulting
FLOORING CONTRACTOR Conslab Ltd
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER BBR Contech (New Zealand)

ARENA CENTER, ZAGREB, CROATIA

Speed and practicality

A shopping mall – the Arena Center – is being built near to the grandiose multi-purpose Zagreb Arena sports hall and again BBR Adria – the Croatia-based BBR Network Member is on the scene.

The slab structure was executed using slab post-tensioning – the total area of post-tensioned slabs is around 72.000 m^2 and the remaining slabs were executed using prefabricated structural elements. The vertical bearing structure consists of prefabricated RC columns and seismic shear walls, partially joined after slab stressing. Prefabricated columns were partially left without concrete – with only reinforced bars passing through – in preparation for the PT slab concrete to fill the voids.

The project required a complex PT design to cope with cantilevering galleries and pedestrian bridges – as well as to provide tenants, including a multi-screen cinema, restaurant and supermarket, with the facilities and space they needed.

The BBR VT CONA CMM 106 monostrand post-tensioning system, with 150 mm^2 1,860 MPa strand, was used to complete the 70,000 m^2 of slabs in eight months. The monostrand post-tensioning technology was a great advantage for the project, due to the speed and practicality of execution, larger casting segments and faster work progress during winter months. ●

TEAM & TECHNOLOGY

OWNER Trigranit Laniste d.o.o.
MAIN CONTRACTOR MI GRUPA (Mucic & Co-Dugopolje, Medjimurje graditeljstvo-Cakovec, Tromont- Split)
DESIGNER Berislav Medic (UPI-2M Zagreb), Miljenko Kovac and Predrag Presecki (K.A. biro Cakovec)
TECHNOLOGY BBR VT CONA CMM monostrand
BBR NETWORK MEMBER BBR Adria d.o.o. (Croatia)

WESTLAND MILK PRODUCTS, ROLLESTON, NEW ZEALAND

CONSOLIDATION for growing business

With a little help from BBR Contech, a new 17,000-square-metre structure now consolidates Westland Milk Products' three existing facilities into a single storage and distribution hub in Rolleston's industrial zone.

Sitting right alongside a road and purpose-built railway line, the new facility enables the company to move 20 and 40 foot containers – weighing about 21 and 31 t respectively – from road and rail trucks by forklift, then to the drystore entrances for de-stuffing and stacking by smaller forklifts. In an average year, that means about 60,000 t of product!

Inside, the drystore features a 165 mm deep post-tensioned floor slab capable of handling a forklift axle load of 110 kN. Post-tensioned by BBR Contech under contract to Calder Stewart Industries using BBR CONA 0405 flat tendons, it was created in nine pours in rows of three slabs, each separated from the other with armored sliding joints. Each pour was synchronized with the drystore's roof construction, enabling a controlled environment and mitigating the effects of spring temperatures and winds.

Outside a heavy-duty, 300 mm thick post-tensioned concrete loading apron is designed to support two containers stacked two-high side-by-side, and 102 t of forklift axle loads. Constructed in five separate pours, it also required larger capacity BBR CONA 0506 flat tendons with additional reinforcing steel and under slab support beams at the perimeter. It is an incredibly strong solution that also reduces the risks of product contamination, which makes it eminently suitable for its use. ●

TEAM & TECHNOLOGY

OWNER Westland Milk Products

MAIN CONTRACTOR
Calder Stewart Industries Limited

DESIGNER Babbage Consultants Ltd

TECHNOLOGY BBR CONA flat

BBR NETWORK MEMBER
BBR Contech (New Zealand)

DUBAI SPORTS CITY, UNITED ARAB EMIRATES

Sporting heartland

Darren Wallis, Business Development Manager for BBR Network Member **NASA Structural Systems LLC** reports that Dubai, in the United Arab Emirates, is creating one of the world's premier sporting destinations.

Dubai Sports City will be the world's first purpose-built sports city. Set on 50 million square feet of land, it will feature four magnificent stadiums, an 18-hole championship golf course and will host the first purpose-built Manchester United Soccer School facility in the world. It will also incorporate premium residential properties, superb shopping, and entertainment and dining, and a vibrant commercial district.

Structural Systems is playing a significant role in the creation of this iconic city, with current involvement in the design and construction of 240,000 m^2 of bonded post-tensioned floors for nine residential towers. With further projects in hand in the dedicated sports destination, including Reem Dubai Contracting's project 'Chess Tower', Structural Systems is becoming known around Dubai Sports City as the premier post-tensioning partner.

So far, Structural Systems has designed, supplied and installed in the order of 950 t of pre-stressing strand within the Dubai Sports City, with further projects expected as the city develops.

During the recent construction boom in the Gulf region and with rapid construction being desirable to contractors, post-tensioned flat plate designs were the preferred solution to maintain the tight construction programs and to minimize the requirement for formwork and back-propping. Although the rapid development in the region has simmered, post-tensioning flat plates – as used on all the above projects – still remain the preferred method of construction here.

An interesting fact in the Gulf Region is the local authorities' usual requirement for a bottom mat of reinforcement throughout most PT slabs. Our standard post-tensioned design practice – of minimizing the reinforcing steel requirement with careful consideration of restraint, levels of pre-compression and proper detailing – was modified to effectively utilize the bottom mesh and allow the designer to provide reduced post-tensioning quantities.

TEAM & TECHNOLOGY

TECHNOLOGY BBR CONA flat

BBR NETWORK MEMBER
NASA Structural Systems LLC
(United Arab Emirates)

SELAYANG SPRINGS, KUALA LUMPUR, MALAYSIA

Simplicity, space and savings

The developer of the new Selayang Springs high-rise residential development wants a neat and flat soffit while ensuring construction is practical and cost is economical – Malaysia-based BBR Construction Systems is helping to achieve this.

The development consists of four phases with 17 to 20 floors of condominium and a five level car park with an area of 2,390 m^2. The tower structure on top of the transfer floor consists of reinforced concrete walls and slabs. To minimize construction time, PT plate with a flat formwork has been adopted. Other advantages over the conventional system are higher headroom and greater economy.

BBR CONA internal 1205 tendons were placed in both directions and profiled to balance the loadings. Tendons which are longer than 30 m were detailed with two live anchorages to handle the higher friction and wobble prestress losses.

TEAM & TECHNOLOGY

OWNER Selayang District Council, Malaysia

DESIGNER
BBR Construction Systems (M)

TECHNOLOGY BBR CONA internal

BBR NETWORK MEMBER
BBR Construction Systems (M) Sdn Bhd (Malaysia)


ITE College West, Singapore

EDUCATION SECTOR PROJECTS, UK AND SINGAPORE

LEARNING strategy

BUILDINGS

Education systems are constantly under pressure to keep up-to-date with ever-changing economic requirements, the development of new technologies and indeed the needs of communities they serve. It is perhaps no surprise therefore that the BBR Network has recently carried out four major education sector projects.

In Singapore, the Institute of Technical Education (ITE) is consolidating its smaller campuses into regional campuses and the creation of a new college has included major post-tensioning works. Meanwhile, in the UK the UK's Building Schools for the Future (BSF) program, has led to our involvement in the construction of three new schools.

CAMPUS CONSOLIDATION, SINGAPORE

The new 9.54 hectare **ITE College West** site in Singapore comprises seven building blocks, a track and field seating, a swimming pool and an innovation walkway. Boasting of some 22 functioning hotel rooms, restaurants, retail shops, a convention centre and even a tourist information centre, the new ITE College West is set to be both a structural and architectural icon in the region.

Working closely with the structural consultant right from the tender stage of the project, **BBR Construction Systems Pte Ltd (BBR CS)** was responsible for the design of all post-tensioned elements throughout the seven building blocks and the Innovation Walkway-cum-Event Plaza. BBR CS was also responsible for supplying, installing and stressing works for PT elements during the construction stage. BBR CS is proud to have been a part of the team behind this iconic project that tops the charts in terms of PT tonnage for two years running. With close to 1,000 t of PT used in this project, almost the entire design and drafting team contributed, at some point, to this project. →

Richard Rose Central Academy, Cumbria


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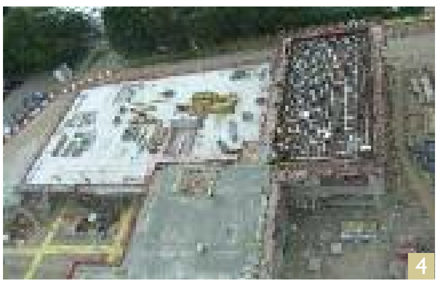

4

2 CROWN WOODS SCHOOL, GREENWICH

The new **Crown Woods Secondary School** in Greenwich, London is a nine form entry school which will be a 'collegiate' with three mini-colleges offering education to pupils aged 11-16 and a sixth form college for 16-19 year olds – each college will have 450 pupils.

Nicholas Hare Architects provided the initial concept and **Structural Systems** worked closely with BDP to fine tune the initial design to produce a flat slab post-tensioned scheme. Balfour Beatty appointed Structural Systems so that the initial design could commence with the rest of the design team and then novated them to Balfour Beatty's chosen frame contractor, A J Morrisroe to carry out the full design and installation of the post-tensioning.

The design has nine pavilion buildings linked by external covered walkways. In addition to the colleges, other buildings house the specialist teaching areas, such as design/technology, music and sport. The checkerboard arrangement of the buildings creates strongly defined courtyards and maximizes use of natural light.

Post-tensioning was used for some 8,000 m^2 of 250 mm thick slabs. Imposed dead loads were 1.8 kN/m^2 with a live load of 4.0 kN/m^2, except for the roof which had a dead load of 1.0 kN/m^2 and a live load of 0.6 kN/m^2. The column layout was typically 7.65 m x 7.80 m.

3 SUSTAINABLE CHOICE, CUMBRIA

The scheme design for the new **Richard Rose Central Academy,** in Cumbria, England, specifically looked to use post-tensioning, so that the benefits of thinner slabs and reduced material content could be fully exploited.

The three storey building to the east of Carlisle city centre consists of a main three storey atrium space, bounded on both sides by teaching accommodation. Two multifunctional halls sit within the atrium and offer a range of interfaces with the teaching accommodation. The main learning accommodation is located on either side of the atrium and is traversed by wide feature staircases and steel bridge links.

The exposed slab soffit has a high quality finish and is complimented by the reduction of down-stand beams that a post-tensioned slab typically offers. Down-stand PT beams 600 mm deep were required under transfer columns at level 1 and for atypical spans, where a 450 mm deep PT beam was

utilized. The slab depth varied, but was typically 250 mm deep to cater for the 9.75 m end span carrying 4 kPa of live load. In addition, a 3.45 m cantilever required a 450 mm deep PT beam in order to control deflection at the cantilevered end.
The area of just over 10,000 m^2 was completed in 15 pours, within a tight program, through the winter months with subzero temperatures commonplace. Careful measurement of the in-situ concrete cube strengths allowed early release of the slab formwork providing huge time savings in the frame program. Typically the formwork was released after five days during the colder spells – a feat not easily achieved using traditional RC construction.

Local insight: The Greenwich Meridian

THE MERIDIAN LINE is an imaginary line which runs from the North Pole to the South Pole. By international convention, agreed in 1884, it runs through 'the primary transit' instrument – the main telescope – at the Royal Observatory in Greenwich.
It is known at Zero Longitude and it is the line from which all other lines of longitude are measured. This includes the line that runs 180 degrees away from Greenwich, also known as the International Date Line.
There have been many meridian lines during the course of history including nine lines at Greenwich alone!
For listeners of the BBC's World Service, Greenwich Mean Time (GMT) will be a familiar expression. GMT represents the mean – or average – time that the earth takes to rotate from noon-to-noon. All time zones are measured from the Greenwich Meridian and although it was replaced in 1972 by atomic time (UTC), it is still widely regarded as the correct time for every international time zone.

4 HIGH QUALITY FINISH, GREENWICH

From a very early stage, it was known that a reinforced concrete frame with post tensioned slabs was the best solution for London's new **Thomas Tallis School** in Greenwich.
The school comprises six blocks over three levels – joined by various walkways – providing 14,500 m^2 of post-tensioned suspended slab.
Most levels are 225 mm thick except for the roof which was 240 mm. Column layout was typically 7.40 m x 7.40 m. Imposed dead loads were 2.2 kN/m^2 with a live load of 5.0 kN/m^2, except for the roof which had a dead load of 2.3 kN/m^2 and a live load of 1.5 and 7.5 kN/m^2.
A high quality finish was necessary to the soffit of the slabs, as in many areas, an exposed soffit was required. The 1,950 pupil secondary school will be equipped with a gymnasium to meet the British Gymnastic and British Judo Association's requirements and has already qualified as a 2012 Olympic training base camp.


4

TEAMS & TECHNOLOGIES

1 2 3 4
TECHNOLOGY BBR CONA flat

1 ITE COLLEGE WEST
OWNER Institute of Technical Education / Gammon Capital Consortium
MAIN CONTRACTOR Gammon Construction Singapore
ARCHITECT DP Architects
STRUCTURAL CONSULTANT Beca Carter Hollings & Ferner
BBR NETWORK MEMBER BBR Construction Systems Pte Ltd (Singapore)

2 CROWN WOODS SECONDARY SCHOOL
OWNER Greenwich Council
MAIN CONTRACTOR Balfour Beatty
Consultant Building Design Partnership (BDP)
BBR NETWORK MEMBER Structural Systems (UK) Ltd

3 RICHARD ROSE CENTRAL ACADEMY
OWNER Cumbria County Council
MAIN CONTRACTOR Kier Construction
Consultant Building Design Partnership (BDP)
BBR NETWORK MEMBER Structural Systems (UK) Ltd

4 THOMAS TALLIS SCHOOL
OWNER Greenwich Council
MAIN CONTRACTOR Balfour Beatty
Consultant Building Design Partnership (BDP)
BBR NETWORK MEMBER Structural Systems (UK) Ltd

Building a healthy future

FIONA STANLEY HOSPITAL, PERTH, AUSTRALIA

Planning for a healthy future is a high priority for the Western Australian Government. Tony Cotham describes how BBR Network Member, Structural Systems Ltd, is contributing to Western Australia's extensive health reform program.

In 2003, the WA Government conducted a review to determine how to prepare for the future demands on the State's public health system due to a rapidly growing population. The outcome was a commitment to an ambitious and widespread health reform in which existing hospitals were to be expanded and new hospitals were to be built.

The A$2 billion Fiona Stanley Hospital development is an integral part of the State-wide hospital reconfiguration plan and is to become the major tertiary health facility in the south metropolitan area, offering services to communities in Perth's southern suburbs.

The 783-bed hospital will offer comprehensive health care services including:

- a full range of acute medical and surgical services
- the State burns service
- the 140-bed State rehabilitation service
- state-of-the-art emergency care which will support a major trauma centre
- comprehensive cancer services including radiotherapy treatment facilities, medical oncology and haematology
- renal transplantation and dialysis services
- a mental health unit containing a secure wing and a mother and baby unit
- obstetrics and neonatology services
- child and adolescent services
- facilities for pathology, bio-medical engineering and cell tissue manufacturing
- a modern medical imaging centre that will provide fast and accurate information to clinicians
- a world-class medical research facility to be built in conjunction with WA universities and the Western Australian Institute for Medical Research.

The forward earthworks for the project were completed in early 2009 under a separate contract, with construction commencing in July 2009. Construction is expected to be completed in late 2013, with the hospital becoming operational in 2014. Once completed, the health facility will provide over 150,000 m^2 of usable floor space.

Structural Systems is contracted by Brookfield Multiplex Construction to supply and install the reinforcement and post-tensioning to the main hospital. The nine storey building is expected to take 2½ years to complete and will contain 643 of the 783 beds, mostly in single, private rooms. The four lower podium levels are designed as conventional reinforced slabs supported by post-tensioned beams. The main wards are located within six upper tower levels, which are designed as fully post-tensioned flat plates. Once completed, the main hospital building will contain over 530 t of slab post-tensioning and 5,200 t of reinforcement bar and mesh.

We worked closely with engineering consultants, Bruechle Gilchrist & Evans, during the preliminary design of the ward levels to incorporate a fully post-tensioned slab. The post-tensioned design was one of several concepts being explored, including precast concrete and conventional reinforced concrete.

Concerns were raised about vibrations and noise within the structure as post-tensioned slabs are typically much thinner than conventional slabs. This was overcome by adopting a minimum slab thickness of 300 mm which, despite being thicker than structurally required, remained the most economical method. The post-tensioned system also allows for earlier removal of formwork for re-use elsewhere and results in a faster construction program.

In focus: Professor Fiona Stanley

Perth's new hospital is named after Professor Fiona Stanley, an eminent Western Australian doctor and the 2003 Australian of the Year, who has dedicated her life to researching the causes of major childhood illnesses and birth defects so they can be prevented.

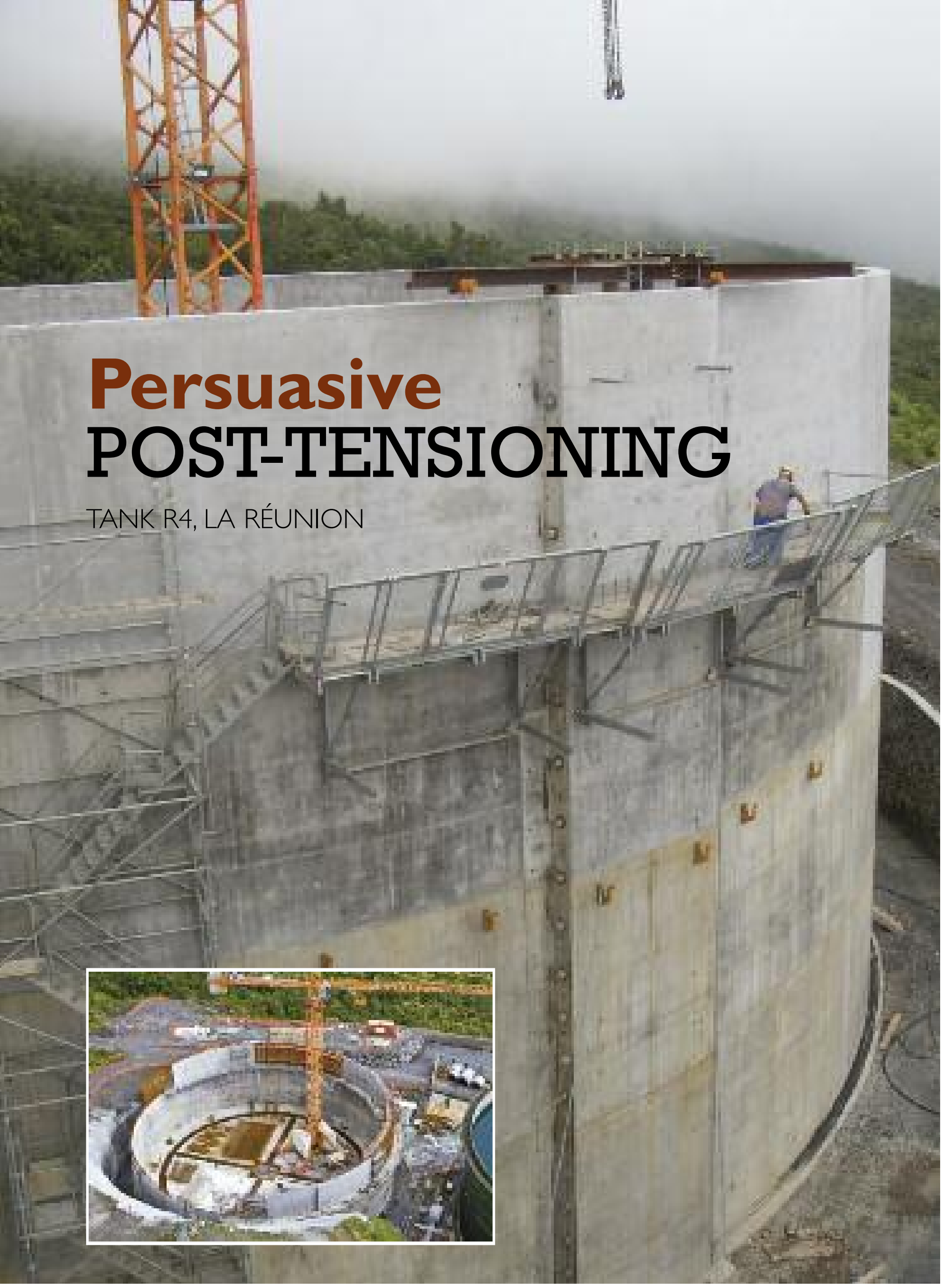
Her work has been widely recognised and she has received many awards and honours including the Companion of the Order of Australia (1996) and the Centenary Medal (2001). In 2004, Professor Stanley was honored as a 'National Living Treasure' by the National Trust. She is also the UNICEF Australia Ambassador for Early Childhood Development.

TEAM & TECHNOLOGY

OWNER Health Department of Western Australia
MAIN CONTRACTOR Brookfield Multiplex
DESIGNER BG&E Pty Ltd
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER
Structural Systems Limited (Australia)

Persuasive POST-TENSIONING

TANK R4, LA RÉUNION



This new water tank is situated on a hillside in the south east of La Réunion, a beautiful French island in the Indian Ocean. Claude Néant of ETIC, the French BBR Network Member, describes how it was constructed alongside three existing steel tanks which were erected ten years ago, as part of energy-provider EDF's hydroelectric installation.

EDF was persuaded to accept a new construction solution, developed by main contractors JV Demathieu et Bard-GTOI, in association with ETIC. This solution involved replacing the traditional steel wall approach with a post-tensioned concrete solution. It was difficult to persuade EDF to use PT concrete, because the site is on the east coast of the island which has higher rainfall than the west.

The client's eventual acceptance of our proposal was driven by a number of factors. The international references of the BBR Network, along with ETIC's excellent reputation – particularly on La Réunion over the last five years – were compelling. When the latter combined with the great experience of the main contractors, who had been involved in large, technically complex viaducts for the island's 'Route des Tamarins' highway, EDF were convinced that this was the appropriate solution.

The reward for all the partners came in the form of a successful first watertightness test – without any leakage – thanks to the PT solution developed for the walls.

PROJECT OVERVIEW

This structure is a 18.6 m high circular tank with a diameter of 46 m and wall thickness of 45 cm. The post-tensioning was designed with 1,860 MPa BBR VT CONA CMI tendons, These tendons were placed in a horizontal position and each one was

approximately 79 m long – in other words, half the circumference of the circular tank. The tendon ends were anchored on a special, lateral concrete rib – and there were four ribs around the circumference.

Grouting was performed with a special cement, and the ratio of the tendons with this design was almost 68 kg per cubic meter of concrete walling.

PT CONSTRUCTION

The tank wall was erected step-by-step, with the concreting of various small panels. The length of the steel sheath was adapted to the length of the reinforcement bars and prefabricated in panels before they were erected. On each end of the sheaths, special couplers were installed to assure a good connection and perfect watertightness with respect to grouting of the tendons in the final step of our post-tensioning work.

The ribs were concreted, with their anchors, by means of a special steel formwork erected with the corresponding panel of the wall.

The tendons were installed using the strand-by-strand method and with a standard pushing machine. A two-stage stressing operation was carried out. There were three teams – one per rib and two for the stressing of the first family of tendons, starting near the ground and finishing at the top of the tank. Second stage stressing was carried out for the two last ribs. We checked the friction coefficient of the tendons by using special captors connected to a computer.

TENDON GROUTING

The grouting of the tendons was achieved with the help of three grouting machines supplied by ETIC. EDF required us to conduct an acceptance test for the special grout we proposed to use. This test, described in the European Standard EN 447, consists of firstly, testing the preparation of the grout and secondly, verifying the exudation of the compound after several hours. We carried out an inclined tube test – using special transparent five meter tubes, fixed to a steel frame erected at an angle of 30 degrees to the ground. ●

TEAM & TECHNOLOGY

OWNER EDF

MAIN CONTRACTOR
JV Demathieu et Bard + GTOI

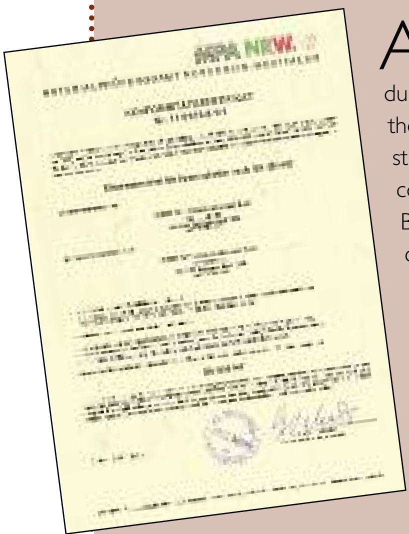
CONSULTANT EDF

DESIGNER CTE

TECHNOLOGY
BBR VT CONA CMI internal

BBR NETWORK MEMBER ETIC S.A. (France)

Technical insight: BBR grout to latest European Standards



As featured in the 2008 edition of CONNAECT, grout plays a key role in the performance and durability of PT tendons. Grout not only provides the necessary bond between the strands and structural member, but also ensures excellent corrosion protection for the prestressing steel. Back in 2007, BBR devised and held a comprehensive grouting seminar where all BBR PT Specialists were fully trained on the latest European Standards relating to grouting requirements, procedures and test methods. Since then, BBR Network Members have adopted the new standards and are continuously educated and annually audited by the ETA Holder.

EUROPEAN STANDARDS EN 447, 446 AND 445

The latest European grouting standards are:

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

These provide the basic requirements for the approval of cement grout in compliance with EN 1992, Eurocode 2: Design of concrete structures, prEN 13670: Execution of concrete structures and ETAG 013: Post-tensioning kits for prestressing of structures.

TESTING REGIME

The testing regime includes three levels:

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

The test methods are prescribed in EN 445.

PROPERTIES OF GROUT

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

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

BBR GROUT MIXTURES AND EQUIPMENT

BBR grout mixtures are homogenous mixtures of cement, water and admixtures. Grouting equipment comprises a mixer, pump and necessary connection hoses, valves and measuring devices.

Grout mixtures, properties and procedures provided by BBR PT Specialists fulfill the latest European Standards. All BBR Network Members employ qualified and trained personnel in grouting and use only prime materials, as well as leading equipment, to produce excellent grout. Furthermore, BBR grout is assessed and certified by an independent Notified Body.

EGG SHAPED DIGESTER, PERTH, AUSTRALIA

CREATING ROOM for growth

The Water Corporation of Western Australia has utilized egg-shaped digesters (ESD) for waste water treatment for the past 15 years. These unique-looking structures have proven to give reliable service and recently, reports Andrew Withers of Australian BBR Network Member Structural Systems, the construction of an additional ESD with a capacity of 8,000 m^3 was required to meet the load demands of the growing population in Western Australia.

Structural Systems was involved in the construction of the very first egg-shaped digester for the Water Corporation and was called upon again to perform the post-tensioning works on the construction of the latest ESD. The ESD uses anaerobic digestion processes to reduce the volume of waste water sludge. Constant mixing maintained at 35 degrees Celsius ensures the sludge is produced into by-products that are highly valued by the agricultural industry.

ESD STRUCTURE

The structure of the ESD required both vertical and horizontal post-tensioning. A clean look for the outside was preferred by the client which meant the typical blister type arrangement for the horizontal stressing was no longer acceptable, Structural Systems instead adopted a 'Z' type stressing block.

TENDON INSTALLATION

A total of 94 horizontal BBR VT CONA CMI tendons were installed, ranging from two to ten strands per tendon. The horizontal tendons were fabricated on the ground and individually installed by a tower crane. Eighteen vertical tendons looped from the top of the structure to the bottom and back to the top. The ducts were installed for each individual pour without the strand for ease of constriction and once the structure reached the top, the vertical tendons were lowered into the ducts and 'pulled' back up to the top using a tower crane. Over 54 t of strand was installed on the project.

STRESSING AND GROUTING

By using the 'Z' type stressing blocks, new curved stressing noses had to be fabricated with friction losses calculated to ensure the correct load was applied. A combination of horizontal-vertical-horizontal stressing kept the crew very busy with scaffolding being erected ahead of the work face. Grouting was done by high pressure colloidal mixers to ensure no voids remained in the structure A close relationship between the client and Structural Systems ensured the project went smoothly.

TEAM & TECHNOLOGY

OWNER Water Corporation, Perth
MAIN CONTRACTOR Alliance EPC Partners – W2W Alliance (Water Corporation, Thiess and Black & Veatch)
DESIGNER Ingenieurbüro Branti, Germany
TECHNOLOGY
BBR VT CONA CMI internal
BBR NETWORK MEMBER
Structural Systems Limited (Australia)

PAGCOR PUMPING STATION & RESERVOIR, METRO MANILA, PHILIPPINES

High water in Manila

With the decision to set up an 'entertainment city' on the reclaimed area of Manila Bay, in Pasay City, Metro Manila, the task of supplying the water requirements for the new 'city' fell on Maynilad Water Services, Inc. (MWSI), the water concessionaire for the West Zone of the Philippines' National Capital Region. Rey Singh of BBR Philippines describes this unusual project.

Entertainment City is an integrated entertainment complex, owned by the Philippine Amusement and Gaming Corporation (PAGCOR), which will sit on 120 hectares of reclaimed land. To supply its water requirements and the partial water requirements of the West Concession Area, the construction of a 24 million liter capacity water reservoir was required.

TECHNICAL ASPECTS

MWSI tasked the structural engineers to prepare the design based on the land available for the reservoir. The configuration of the land, influenced by the prohibitive acquisition costs, dictated a high, almost triangular reservoir. The final design called for a three-sided footprint with sides of 47.5 m, 52.5 m and 64.9 m. The height of the structure is 27.7 m, including the 1.5 m thick mat foundation and 300 mm structural concrete roof. Also, the designers required four levels of tie-beams to help the reinforced concrete walls resist the hydrostatic pressure and to maintain the 1,000 mm wall thickness.

POST-TENSIONING WORKS

Primarily, post-tensioning was introduced to resist the water pressure exerted by the 24 m storage height. The engineers prepared a post-tensioned design for the mat foundation, tie-beams, wall beams, roof beams and roof slab to reduce the concrete sections and the reinforcing steel bar requirements and to facilitate the construction works. They specified the use of 12.7 mm galvanized PT strands for the post-tensioning works to add another layer of corrosion protection for the prestressing steel in the aggressive marine environment of the project.
For the mat foundation and the roof slab, we used BBR CONA flat 405 tendons and BBR CONA internal 705 tendons for the post-tensioned tie, wall and roof beams.
With the completion of the structural works in August, 2010, the benefits of BBR Technology and expertise in building vital infrastructure for the Filipino nation were once again demonstrated.

TEAM & TECHNOLOGY

OWNER Maynilad Water Services, Inc.
MAIN CONTRACTOR DM Consunji, Inc.
DESIGNER DCCD Engineering Corporation
TECHNOLOGY BBR CONA flat
BBR CONA internal
BBR NETWORK MEMBER
BBR Philippines Corporation

CEMENT SILO,
ALICANTE PORT, SPAIN

LEISURE MOVE for cement silo

This silo is the first of nine which will be constructed in the extension of the Port of Alicante, explains José Luis Plaza Bacete of Spanish BBR Network Member, BBR PTE. One of the principal aims of building the new port extension was the relocation of these silos. The motivation for the APA (Port Authority) is the freeing-up of the Levante Dock for exclusive use of cruise liner traffic and sporting events. The Port of Alicante will be the starting point for the Volvo Ocean Race and Alicante will become the VOR headquarters until 2018, with the consequent economic benefits this will bring for the city.

The current economic crisis has seen demand fall, so initially only one cement silo has been constructed – and this might enter service in spring 2011.

The 36 m high silo has an external diameter of 20.8 m and wall thickness of 0.4 m. Given the features of this cylindrical silo, sliding formwork was the most appropriate technique for its construction.

SLIPFORM PROCESS

The slipform process involved building twin inner and outer wooden formwork rigs, each of which was 1.2 m high and covered with a 0.5 mm steel sheet to provide a fair-faced concrete finish. Thirty six hydraulic jacks were uniformly distributed and installed around the silo and fitted to the beams of the yokes with wooden collars. Next, three different working platforms were installed at three levels. The upper platform allowed the supply and installation of vertical and

horizontal reinforcement, while from the intermediate level, concrete was poured into the formwork. The lower level was for wall surface repairs.

The whole slipform rig was moved upwards by hydraulic jacks, all of which were controlled by the same central unit. The sliding rate was approximately 3 m per day – as a result, the slipforming of the cement silo was completed successfully in less than ten days.

PROGRAM BENEFITS

One of the main benefits of using this method of construction is the short program required and, as a consequence, this also reduces the budget in terms of labor and crane hire, as well as allowing follow-on work to be started earlier. ●

TEAM & TECHNOLOGY

OWNER Cimsa Cementos
MAIN CONTRACTOR ISO (Iberia de Servicios y Obras)
DESIGNER Bakken, S.A.
TECHNOLOGY Slipform
BBR NETWORK MEMBER BBR PTE, S.L. (Spain)

Connecting communities safely

PEDESTRIAN BRIDGE, BLACKBURN, SOUTH AFRICA

The Blackburn Pedestrian Bridge is the first stay cable bridge project awarded to BBR Network Member **Structural Systems Africa** as a specialist subcontractor. Paul Heymans takes up the story. →

Structural Systems Africa's (SSA) work included the supply, installation, stressing and grouting of the post-tensioning to the bridge deck, as well as the supply, installation and tensioning of the BBR Pin Connector stay cable system. At 160 m in length, it is one of the longest cable-stayed pedestrian bridges in the world and sits 10 m above the dual carriageway N2 highway, located in Durban, South Africa. The two main 70 m long spans are mirrored about the 61 m high A-frame concrete pylon. There is an 18 m end span on the western end which does not incorporate any stay cables.

The bridge allows pedestrians from the nearby Blackburn community to cross safely over the highway to the Umhlanga Ridge Town Centre. Prior to the completion of the bridge, pedestrians had to cross the free-flowing N2 highway at road level, which has recently seen a dramatic increase in traffic since the opening of the new King Shaka International Airport in La Mercy, just north of Durban. Rather than constructing the bridge using the balanced cantilever method – which would be typical for construction over four lanes of traffic – the bridge was constructed using staging. This required the extensive use of scaffolding which had to bridge the highway to ensure two lanes of traffic per carriageway remained open, whilst allowing easy access for both post-tensioning and stay cable construction works.

POST-TENSIONED DECK

The concrete deck is only 4.9 m wide, typically cast in 16 m segment lengths, with edge beams either side of the deck to accommodate four 12-strand PT tendons with 1206 BBR VT CONA CMI multi-strand anchors and a 200 mm thick deck slab spanning between the beams.
The longest of the deck tendons is 72 m which is about the centre of the pylon. Stressing of tendons was carried out with a 300 t centre-hole multi-strand jack, handled by a small SSA purpose-made gantry due to limited overhead crane reach. We designed job-specific permanent steel grout caps for the coupling anchor heads to ensure that the continuity of each adjoining segment was not delayed by grouting of the completed segment – and designed such that the strands did not clash with the caps after coupling to the coupler.

CABLE STAYS

There were 16 sets of stay cables supporting the bridge deck, ranging in length from 25 m to 72 m, with eight pairs of stays either side

of the pylon. The stay cables for this bridge are on a small scale in terms of the number of strands per stay, with each stay consisting of four 15.7 mm galvanized HDPE coated strands inside a black HDPE stay pipe. The BBR Pin Connector 00406 system was used for the stay cable anchors. Pre-assembly of the stay cable sets was completed on the bridge deck, with the galvanized top fork anchors fitted to the stay cable prior to it being lifted and secured to 50 mm stainless steel support plates, cast into the top of the pylon, by means of a pin to allow rotation of the top anchor. After this, the stay cables were inserted through the bridge deck into the bottom cast-in stay cable anchors and tensioned below deck.

The tensioning of the stays was completed below the bridge deck in two stages. The initial tensioning typically went to an average of 80% of the expected final stressing value. The second stage of tensioning was effectively a fine-tuning of the stay cables, based on the behavior of the structure after Stage 1 stressing and also the actual forces in each stay cable pair.

International support was provided by the Structural Systems Group's Sydney office, with BBR VT International supplying detail design drawings and specifications.

TEAM & TECHNOLOGY

OWNER South African National Highways Agency Limited (SANRAL)

MAIN CONTRACTOR
JT Ross / Devru Construction JV

DESIGNER
SSI Consulting Engineers (A DHV Company)

TECHNOLOGY
BBR VT CONA CMI internal
BBR Pin Connector

BBR NETWORK MEMBER
Structural Systems (Africa)

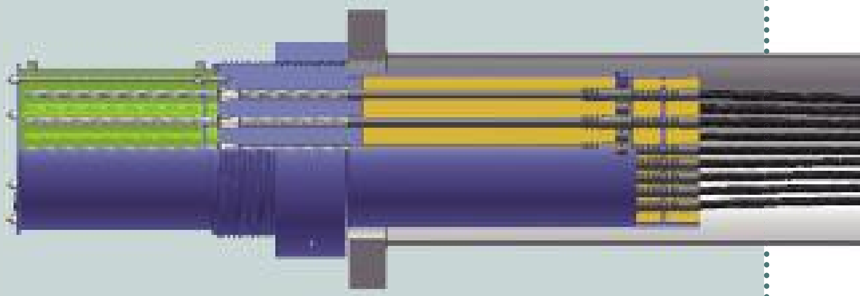
Technical insight: BBR HiAm CONA – countering bending

OPTIMIZED PATTERN

Within the BBR HiAm CONA anchorage device, all strands are anchored individually by means of wedges and run in their own individual plastic tube. In the free length of the cable and at the location of the deviator, the strand bundle follows a symmetrical circular pattern to fit inside a compact stay pipe, whereas at the location of the anchor head the pattern is hexagonal to provide for optimum and regular wedge spacing. The individual tubes within the socket are arranged so as to initiate the strand transition from the hexagonal to the circular pattern. This arrangement allows the most extremely deviated strands in the neutral position of the cable a wider additional working range under the influence of cable oscillations and angular deviations, while still keeping the overall length of the anchorage device short.

INDIVIDUAL ELASTIC GUIDING

Before exiting the socket, each strand is individually and independently supported with a hyper-elastic guide tube (SmaCu Guide). The SmaCu Guide is straight on the inside and has a ribbed section on the outside to facilitate bending whilst maintaining an effective bond with the surrounding filler material. It is designed to support each strand for all applicable design deviation angles over its entire length and thus minimizes the curvature imposed on the strands. The SmaCu Guide ensures that the curvature within each individual strand is minimal for the applicable deviation angle and also non-constant. Independently of the applicable deviation angle, the maximum curvature of the strands does not exceed 1/3500, which results in index bending stresses in the strand of only 145 MPa.



Cable-stays for conveyors

Andrew Withers of **Structural Systems Limited,** the BBR Network Member in Australia provides an overview of a most unusual stay cable application for BHP Billiton Iron Ore – one of the world's premier suppliers of iron ore.

NEWMAN HUB STOCKYARD & SAMPLE STATION, NEWMAN, WESTERN AUSTRALIA

The Mount Whaleback Mine Ore Handling Facility is located in Newman, Western Australia and we were contracted to supply, install and stress stay cables to support conveyors used at the Newman Hub for stock piling of iron ore.

The Hub will crush and screen iron ore from Mount Whaleback and satellite pits in the Newman area, removing the need for individual processing plants and also making sure there is a much-reduced processing requirement when the ore arrives ready to be shipped at Port Hedland.

INCREASING INSTALLED CAPACITY

Part of the project consists of two towers that required BBR DINA stay cables to support the conveyors. The towers formed part of the company's Rapid Growth Project 4 (RGP4), which would increase installed capacity across BHP Billiton's Western Australia iron ore operations to 155 million tons-a-year.

STAY CABLE FABRICATION

We supplied all the materials to fabricate the BBR stay cables. Eight cable-stays were fabricated, four each at 28 m and 38 m long. Each stay cable had a BBR DINA Socket 70-7 at its end, with a BBR DINA 707 anchor head to secure the stay cables. This was the first time we had used such large sockets – each one weighed over 370 kg. This huge weight required new systems to be developed for the installation of the stays. All stay cables were fabricated at ground level and lifted into position.

Careful planning with the client and the owner ensured the cables were installed on program.

TEAM & TECHNOLOGY

OWNER BHP Billiton Iron Ore
MAIN CONTRACTOR John Holland
DESIGNER SKM Sinclair Knight Merz
TECHNOLOGY BBR DINA/HiAm stay
BBR NETWORK MEMBER Structural Systems Limited (Australia)

RIVER PILICA BRIDGE, MALUSZYN AND RABA FOOTBRIDGE, PCIM, POLAND

Eminently suitable systems

Bartosz Łukijaniuk and Adrian Dyraga from BBR Polska describes two small-to-medium sized bridge projects in Poland which demonstrate the eminent suitability of the BBR DINA wire stay cable system and of steel bar stays.

1 BBR DINA STAYS – PILICA BRIDGE

The new 56 m long and 13 m wide bridge over the River Pilica has a steel superstructure combined with a concrete deck. The structure is suspended with five pairs of stay cables from each of two inclined steel pylons around 14 m high. The suspension system is made up of BBR DINA stays arranged in a fan shape – five pairs of 7 mm diameter BBR DINA 48-103 stay cables suspending the deck and three pairs of 7 mm diameter BBR DINA 135 stay cables securing the pylon to the abutment. BBR DINA stay cables are fully prefabricated and are delivered to site fully assembled in the appropriate length including corrosion protection. The quick-to-install system offers stay cables ranging from 13 to 199 wires and can be delivered in any color to meet client specifications.

2 FOOTBRIDGE OVER RABA USING STEEL BAR STAYS

Steel bar stays were the perfect solution for the 100 m long footbridge over Raba river. The 3 m wide superstructure consists of two steel girders and a concrete deck. In total two 8 460 MPa M64 stay cables, connected to the 13 m high pylons, carry the superstructure. ●

TEAMS & TECHNOLOGIES

1 2

BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

1 PILICA BRIDGE

OWNER
Local Management of District Roads, Łód

MAIN CONTRACTOR Skanska S.A.

DESIGNER
Biuro Projektowo-Badawcze 'Promost'

TECHNOLOGY BBR DINA/HiAm stay
BBR VT TOBE pot bearing
PT bar
Expansion joint

2 RABA RIVER BRIDGE

OWNER City Council of Pcim

MAIN CONTRACTOR Consortium BBR Polska and Remost S.C.

DESIGNER Biuro Projektowe Wanta S.C. – mgr inz. Andrzei Mikulasik

TECHNOLOGY Bar stay cable
BBR VT TOBE pot bearing
PT bar
Expansion joint

Raba footbridge

River Pilica Bridge

FOOTBRIDGE, KUALA TRENGGANU, MALAYSIA

Birth of an icon

Low Hin Foo of **BBR Malaysia** describes how his company took up the challenge of providing a bridge form which was special and functional to link Warisan Island with Chinatown, and also to provide spectacular views for the annual Monsoon Cup yachting competition.

Warisan Island is a small man-made island located just off Chinatown of Kuala Terengganu on the east coast of the Malaysian peninsula. The Government is making it into a cultural-cum-handicraft center to display and preserve the rich local heritage. To complement this – and as a new tourist attraction – a pedestrian bridge with an striking shape was proposed to link this island to Chinatown.

OUR PROPOSAL

We proposed a tilting arch bridge with hangers supporting a fantastically curved deck. With hangers only on one side – on the inner curve – the public could enjoy unobstructed scenic views of the South China Sea, including its spectacular sunset and the popular Monsoon Cup competition. The white steel arch and deck with the black cables reflect the Trengganu state colors.

STRUCTURAL DESIGN

The arch hanger bridge is designed as an arch fixed to two micropiled foundations, spaced at 31 m. The 12.3 m high steel arch is comprised of steel oval-shaped segments with rolled plate thicknesses from 25 to 30 mm. Nine DINA wire hangers, inclined at 31 degrees, provide support to the 4.5 m wide curved deck. The deck consists of steel pipe trusses overlaid with a cast insitu 125 mm thick concrete slab. The deck is designed to handle a pedestrian live load of 5 kN/m^2.

BBR DINA HANGERS

As the cables are relatively small, using BBR DINA stay cables is most effective in the smaller capacity range. They can be manufactured at the factory, fully-assembled and installed by crane on site. The system has a high fatigue resistance through its proven button head technology. Each hanger has a HDPE duct containing 7 mm diameter galvanized wires of 1,670 N/mm^2 UTS (Ultimate Tensile Strength) which varies from 38 to 48 wires. After cable erection and stressing, they are filled with grease to provide the third level of corrosion protection – in addition to the galvanizing and HDPE pipe.

ERECTION METHOD AND SEQUENCE

While the foundations were being constructed, the four steel arch segments and six deck segments were fabricated off site. After delivery of the arch segments, →

DESIGN Q&A

WHY CHOOSE AN ARCH BRIDGE?

A steel arch bridge is not only elegant in shape, but also allows sufficient pier-free space and headroom for boats to pass below it. Using an arch as the main load carrying member, a relatively thin deck of 900 mm depth could be designed.

WHY IS THE ARCH TILTED BACKWARDS?

The arch is tilted backwards to utilize the arch self-weight to counterbalance the weight of the deck, as well as the pedestrian load which tends to tilt the arch forward.
By tilting the arch backwards 20 degrees from the vertical, the back stay stabilizing cables can be eliminated – which, in turn, delivers an elegant bridge. After the steel arch was erected, it was filled with cement grout to stiffen and strengthen the arch, besides beneficially adding self-weight to the structure as a counter balance.

WHY CHOOSE A CURVED BRIDGE DECK?

The bridge is located at the river mouth. Its deck curves out into the sea making an angle of 159 degrees – almost a semi-circle – over a curved length of 41 m. This optimizes the viewing angle and accommodates more visitors, effectively providing a viewing gallery for the Monsoon Cup venue.

HOW DOES THE DECK WORK WITH HANGERS ON ONE SIDE ONLY?

When a row of hangers is provided on one side, the inner curve, of the deck, the hangers do not obstruct the pedestrians. It also gives a feeling of spaciousness.
The hangers are designed to support the steel truss deck and transfer the loads to the main arch. They work as elastic supports to the deck slab.
If we study a cut section of the deck slab in a two dimensional plane (2-D), the deck structure is not stable at all. This is because the hangers contribute zero stiffness to the support system of this 2-D system, allowing the deck to rotate infinitely.
In order to stabilize the deck, a steel truss system is adopted to provide rotational stiffness in the three dimensional plane (3-D) of the bridge. The steel truss is rotationally stiff and thus supports the deck not only vertically but also rotationally.With each hanger acting as elastic vertical support and the truss system as rotational restraint, the bridge deck section behaves as if cantilevering from this pseudo-support and becomes stable.

WHY IS A CONCRETE NIB PROVIDED AT THE PILECAP?

The steel arch is tilted backwards to use the self-weight to counterbalance the deck weight and pedestrian load. However, pedestrian load is considered as live load which moves around. Thus, when the pedestrian load is not present, the back leaning arch is subjected to a constant bending moment – or cantilevering moment. In order to optimize the design, a concrete nib is provided as a counterweight to balance a portion of the bending moment from the arch when the live load is absent. This concrete nib also provides a higher resistance against the kicking out force from the arch through passive soil pressure. The combination of passive earth pressure and 300 mm diameter micropiles resists the combination of forces and moments induced from the fixed arch action.

they were welded on site and erected on the pilecaps. Each arch base was anchored using 20 50 mm diameter grade 835/1050 bars.

The area below the deck was temporarily backfilled to enable placement of temporary supports to precambered levels of deck. The outer curve side (without cables) was engineered to a higher camber due to the higher anticipated deflections. Each cable was erected using a crane to insert the top end into the bearing plate hole of the arch. Next, the lock nut was fixed to secure the top anchor. Then, the lower end of the cable was lifted and inserted through the bottom bearing pipe and plate at the deck. A chain block was used to bring in the anchor head and then secured with the stressing sleeve. A telescopic joint in the HDPE pipe had been provided near the bottom anchor to facilitate fabrication and to allow movement during erection and stressing.

Initial stressing was carried out using a stressing chair and 36 mm diameter pull rod to lift the steel bridge off of its temporary supports. After concreting the deck, fine-tuning of cables and deck levels was carried out. Then the telescopic joint on the HDPE pipe was electrofusioned to prevent future movement. Finally, grease was pumped into the cables and the anchor caps were installed.

KEY BENEFITS TO CLIENT

The client is happy with the form and aesthetics of the pedestrian bridge. It proved easier for them to have a single point of contact for the bridge, as we did both the design and construction, apart from the foundations. By utilizing our BBR DINA technology and engineering experience, we produced a fabulous bridge and fully met the client's needs. ●

TEAM & TECHNOLOGY

OWNER Public Works Department, Malaysia
MAIN CONTRACTOR
Kumpulan LIZIZ Sdn Bhd
BRIDGE DESIGNER/CONTRACTOR
BBR Construction Systems
TECHNOLOGY BBR DINA/HiAm stay
BBR NETWORK MEMBER
BBR Construction Systems (M) Sdn Bhd (Malaysia)

Geometrical elegance

BBR Technology is used not only in the post-tensioning of structures and stay cable bridges, but also in cable-stayed long span roofs, says Bartosz Łukijaniuk of BBR Polska.

During the last year, our team has used a 22-strand BBR VT CONA CME system to create a cable-stayed roof over a sports hall in Płock, central Poland. This is our third cable-stayed roof project – having completed roofs for a sports hall in Włocławek (2001) and an amphitheater in Płock (2007) – but with an 85 m span, this is the biggest. It is only possible to achieve such long span roofs with PT technology – nothing else is as effective. The 30 m high 5,500-seat sports hall was opened in November 2010 and is now named Orien Arena, which is home of the local Wisla handball club. The circular arena has a diameter of 90 m including a 50 x 50 m sports field. BBR Polska was awarded the contract for delivery, installation, stressing and grouting of the stay cable roof structure.

MAIN ADVANTAGES

The main advantage of cable-stayed roofs is that the tendons are the only structural elements – so the long span roof structure is very light. But a really key benefit is that during the construction stage there is no need for temporary supports or scaffolding – the structure is only load-bearing after it has been installed. Another big point in favor of cable-stayed roofs is that the tendons are protected with HDPE pipes, to which it is very easy to attach different roofing systems.

STAY CABLES

SPORTS HALL ROOF,
PŁOCK, POLAND

BACKGROUND DETAILS

The stays for the saddle-shaped sports hall roof consist of 40 tendons. Twenty one of these are load-bearing and have a concave layout, while the other 19 serve to tighten the cable structure and have a convex layout. All tendons are made of 22 strands – with a UTS 1,860 MPa and a 150 mm^2 cross-section – guided through HDPE pipes. The ultimate tensile force of each single tendon is 6,138 kN.

The tendons are anchored in a steel ring supported on 36 concrete columns. The ring is made of a 1,000 mm diameter steel pipe with a 30 mm thick wall. Concrete column heights are between 15 m and 25 m. The longest tendon is around 101 m long and all tendons are protected with cement grout. In total, we used almost 100 t of stressing steel, nearly 3,500 m of HDPE pipe and 50 t of grout. All of our work was carried out from conventional work platforms in anchorage zones and aerial work platforms.

METHODOLOGY

On account of the 50 to 101 m length and 1.3 to 2.6 t weight of the tendons, it was decided to install HDPE pipes containing two guide strands – and push the remaining strands in afterwards, rather than installing fully prefabricated tendons. When installing such tendons it is very important that individual strands should be of the same length – so we designed a special pushing instrument that supported the anchor head and a special method to achieve this.

Firstly, the concave tendons – the load-bearing ones – were installed. After the HDPE pipes containing the guide strands were installed, the remaining strands were pushed through the pipes. The tendon geometry – that is, the slack in each tendon – was carefully measured by surveyors and, if necessary, the tendons were pulled upwards with a stressing jack.

Next, all tendon nodes – individually designed steel elements – were installed. Onto this prepared structure, we fitted the convex – tightening – tendons. When all nodes were connected to two tendons, the process of pushing the remaining strands began. After a very precise survey of all nodes on the central tendon, the structure was ready for final stressing.

SIMULTANEOUS STRESSING

Stressing was carried out using two stressing sets, each consisting of one 4,800 kN multi-strand stressing jack and a hydraulic pump. Each tendon was stressed simultaneously from both ends.

The stressing of the whole structure was completed very quickly, because the actual effects of the stressing, in terms of tendon geometry, complied perfectly with the numeric model and design requirements. No corrections were needed – all tendons were stressed just once!

Tendon grouting was performed in the very early mornings or at night because of the weather conditions – it was extremely hot in Poland in summer 2010. Each tendon was grouted from both ends.

Well, this was our third cable-stayed roof – but there are still many to build … perhaps there will even be an article in *CONNAECT* 2012 about another cable-stayed roof in Poland!

TEAM & TECHNOLOGY

OWNER City Council of Płock

MAIN CONTRACTOR
Consortium VECTRA S.A. and BBR Polska Sp. z o.o.

DESIGNER Structural design office Modern Construction Design, Poznan, Poland; Henryk Nowacki (the designer of two other cable-stay roofs in Poland; both executed by BBR Polska);

TECHNOLOGY
BBR VT CONA CME external

BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

Upgrading dam safety

The building of dams is firmly rooted in history, with the earliest dam construction taking place in Mesopotamia and the Middle East where dams were used to control the water level in the Tigris and Euphrates rivers. The advent of hydropower saw a surge in dam building and the age of the mega-dam arrived with the construction of the Hoover Dam in 1936. Today, there are around 800,000 dams of diverse sizes and purposes worldwide.

While they offer communities many benefits, it is widely recognized that such structures – should they fail – may present serious risks, not only to the safety of the general public, but also to national and local economies. Therefore, many governments around the world have developed regulatory frameworks for dam safety which are regularly reviewed to ensure the continued safe operation of the infrastructure. Recently revised standards relating to potential seismic events have prompted the upgrading and strengthening of a number of dams. We present brief overviews of three projects carried out by BBR Network Members in Australia and Norway.

1

1 IMPROVING STRUCTURAL STABILITY IN WESTERN AUSTRALIA

Like several other Australian dams, **Wellington Dam** is being upgraded to meet revised safety standards, **Structural Systems** has been constructing permanent anchoring to improve the structure's stability.

Water Corporation have awarded the A$41M (US$37M) Wellington dam upgrade to an Alliance formed by Water Corporation, Leighton Contractors, Structural Systems, Hydro Tasmania and Aecom. The dam is located some 170 km southeast of Perth, near Collie, and is the second largest reservoir (186 GL storage) in Western Australia. The dam was built in two stages, to 19 m in 1933 and raised to 34 m in 1960. The crest width is approximately 350 m.

The upgrade involves installing 28 piers atop the existing spillway which will support a permanent access bridge for the anchor installation works and for future anchor monitoring. A central block will be constructed also on top of the existing spillway which will house 9106 strand permanent anchors up to 70.3 m long. These anchors are equal in detail to those recently installed by Structural Systems at Catagunya Dam, sharing a minimum breaking load of 25,389 kN – the largest ever installed. Additional anchors from 3106 to 6506 will be installed on the non-overflow abutments. Anchoring works include the fabrication, transportation, installation, grouting,

Wellington Dam, Australia

stressing and monitoring of the permanent ground anchors. The anchors consist of 15.7 mm strands, individually greased and sheathed over the free length allowing the strand to extend without restraint, while the remaining 7 m to 12 m of bare strand in the bond length provides fixity via grout to the surrounding rock. Heavy-duty corrugated polyethylene sheathing in the bond zone and smooth sheathing over the free length form a flexible, yet impermeable membrane to protect the strand tendon against corrosion over its 100+ year design life. The anchors will be stressed using a 2,200 t capacity hydraulic jack.

2 CHALLENGE WELL MET IN QUEENSLAND

Tinaroo Falls Dam, owned and operated by SunWater Limited, is located in far north Queensland on the Barron River – approximately a 90 minute drive inland from Cairns. The dam was constructed primarily to provide water to an irrigation scheme and has a storage capacity of 407,000 Megalitres. At the base of the dam, a small hydroelectric generator was recently commissioned. The possibility of a much larger rainfall event than previously predicted, along with seismic considerations, led to the requirement for the dam's structural upgrade.

The use of anchoring technology provided significant advantages to the client – when compared to mass concrete strengthening – in terms of both cost savings and project duration. Early discussions with **Structural Systems** allowed the initial concept of a larger number of small 27 strand anchors to be rationalized to only one large anchor per nominal 15 m wide block of dam, which again saved the client both money and time.

The final design incorporates a total of 32 vertical anchor tendons from 24 strands (Minimum Breaking Load MBL 6,696 kN) up to 75 strands (MBL 20,925 kN) each. The strand used for the anchors is 15.7 mm, MBL 279 kN, as it proved a more economical alternative to the more commonly adopted 15.2 mm, MBL 261 kN strand. All anchors feature BBR VT CONA CMG anchor heads, fitted with low friction strand entry transitions and external threading for future monitoring – utilizing a purpose-built load cell – at typically five year intervals throughout the anchor's 100+ year design life.

Over the years the Structural Systems team has established a reputation as industry leaders in the development and execution of high capacity ground anchors, having built an extensive portfolio of projects including Canning Dam (1999) and Catagunya Dam (2009) in which they developed 91-strand anchoring technology. These projects currently hold the world records for the longest ground anchors (142.02 m), heaviest ground anchors (over 16.5 t) and highest capacity ground anchors (MBL 25,389 kN).→

3

Tinaroo Falls Dam, Australia

Structural Systems' total project scope, as main contractor, included the design and provision of a bridge access system over the spillway, concrete coring and insitu concrete works for the 1,250 mm diameter anchor head blocks and pits, plus 350 mm diameter drill holes for the anchors.
The anchors were manufactured on site using specialist equipment to open each strand, separating and fully greasing each of the seven wires, before inserting into the 20 mm HDPE sleeve for the free length. The bond length is bare strand that is high pressure steam-cleaned and assembled to create an hourglass effect to maximize load transfer into the surrounding rock. Total anchor lengths were up to 79 m with bond lengths up to 12 m.
The anchor holes were prepared for the anchor installation with the insertion of a 280 mm diameter HDPE sheath that fully encapsulated the anchor, providing primary corrosion protection in a flexible but impermeable membrane. A specially developed corrugated sheathing was utilized for the bond length to allow transfer of the anchor loads into the rock. The corrugated sheathing was specially molded in lengths of up to 16 m. The free length portion of the sheathing was smooth extruded HDPE in 7.5 m lengths which were fusion-welded on site to form the required anchor sheath length.

Tinaroo Falls Dam project – **Facts & Figures**

Permanent strand anchors
= 2406 to 7506 x ø 15.7 mm strands

- Permanent anchors – 32
- Anchor sizes – 2406, 3306, 3806, 4706, 5406, 6206 & 7506
- Vertical anchors – 29 m to 79 m long, plus stressing length
- Bond length – 6 m to 12 m each
- Total length – 1,839 m
- Drill hole size – 350 mm diameter
- Minimum breaking load to 20,925 kN
- Test force to 15,694 kN (75% MBL)
- Strand (15.7 mm diameter) – 130 t
- Cement – 250 t

Permanent passive bar anchors
= ø 40 mm grade 1030 bar

- Permanent passive anchors – 110 & 24
- Anchor size – 40 mm diameter
- Vertical anchors – 9 m to 20 m long
- Bond length – 9 m to 19 m each
- Total length – 1,374.7 m
- Drill hole size – 150 & 175 mm diameter
- Minimum breaking load – 1,295 kN
- Cement – 30 t

The assembled anchor tendons, weighing over 7 t, were transported to the dam structure on a series of purpose-built trolleys. Installation of the tendon into the sheathing was achieved with a custom frame which elevated then bent the tendon over a 5 m radius on a series of rollers to a vertical alignment for installation. A large braking winch controlled the rate of tendon descent. Once installed, the anchors were suspended in the holes for grouting which was completed as a three stage process utilizing Class G cement to the bond length and GP cement to the free length. Stressing of the anchor, to a proof load of 75% MBL (maximum 15,694 kN) and a lock-off load of 70% was completed with a 2,200 t capacity hydraulic jack.
Subsequent to the primary crest anchoring being awarded, a variation for permanent passive bar anchors to the crest abutment ends and stilling basin floor was also entrusted to Structural Systems.


2

Svatediket Dam, Norway

3 BERGEN'S RESERVOIR OF MODERN HISTORY

Located between two of the seven mountains that surround Bergen, the 40 km^2 Svartediket (Black Lake) was the first Norwegian lake to have a modern water distribution system and still serves today as the main water supply for the capital of Western Norway. The old **Svartediket dam** is being strengthened to meet the new earthquake regulations, while continuing to fulfill normal load requirements.

From the crest of the dam, 135 rock anchors are being installed into solid rock. The main contractor, NCC Construction, is core drilling the 116 mm and 146 mm holes and BBR Network Member **Spennteknikk** is responsible for supplying and installing the anchors.

With the passage of the new seismic regulations into legislation in many countries, it is anticipated that there will be a significant volume of dam strengthening work coming up for tender.

TEAMS & TECHNOLOGIES

1 WELLINGTON DAM

OWNER Water Corporation

MAIN CONTRACTOR Wellington Dam Alliance (WDA-Water Corporation, Leighton Contractors, Structural Systems, Hydro Tasmania and Aecom)

DESIGNER WDA

TECHNOLOGY
BBR VT CONA CMG ground

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

2 TINAROO FALLS DAM

OWNER SunWater Limited

MAIN CONTRACTOR Structural Systems

DESIGNER SunWater Limited

TECHNOLOGY
BBR VT CONA CMG ground

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

3 SVARTEDIKET DAM

OWNER City of Bergen

MAIN CONTRACTOR NCC Construction AS

CONSULTANT Norconsult AS

TECHNOLOGY BBR CONA ground anchor

BBR NETWORK MEMBER
KB Spennteknikk AS (Norway)

SPECIAL APPLICATIONS

Technical insight: BBR ground anchors

One of the early civil engineering applications of BBR prestressing technology was for anchoring structures into the ground or for stabilizing slopes using ground anchors. Sixty years ago, BBR ground anchor technology was used for the first time on the Maggia Power Station in Switzerland. Since then, ground anchor technology has evolved significantly and is now widely used all over the world. Common applications for ground anchors are:

- Tieback of vertical excavation walls
- Stabilization of unstable slopes
- Securing of structures below ground water level
- Anchoring of tall structures, such as transmission towers and windmills
- Anchoring of concrete dams
- Anchoring of tensile forces of cableways or bridge abutments.

The basic function of a ground anchor is to transmit tensile forces into the rock or soil by means of the:

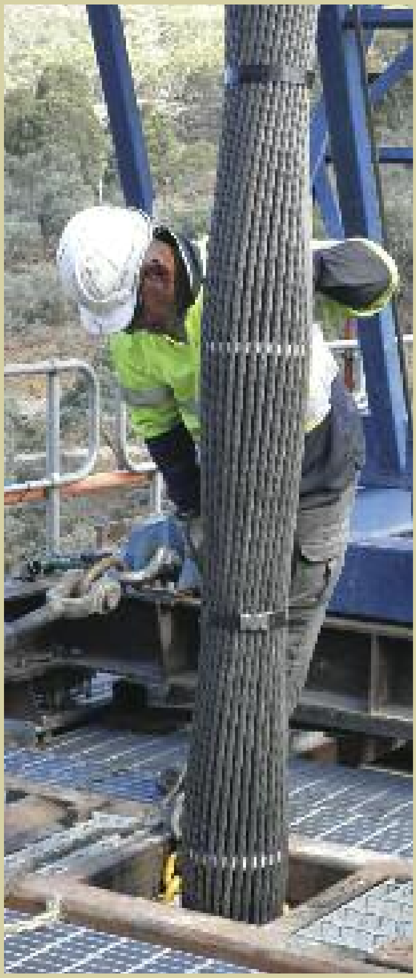
- Anchor – including anchor head, wedges and load transfer element
- Free unbonded anchor length – where the tendon can elongate
- Fixed bonding – where the force is transmitted into the ground through the bond between the tensile element, grout, duct and finally the ground.

Ground anchors are often classified according to their service life, corrosion protection requirements, risk etc., which serve to determine the appropriate corrosion protection.

Permanent anchors are entirely encapsulated in a duct – this is smooth in the free length and corrugated in the fixed length. The tensile elements are individually greased and PE-sheathed in the unbonded length and bare in the bonded length. Inner and outer grout filling ensures highest corrosion protection for a 100+ year design life.

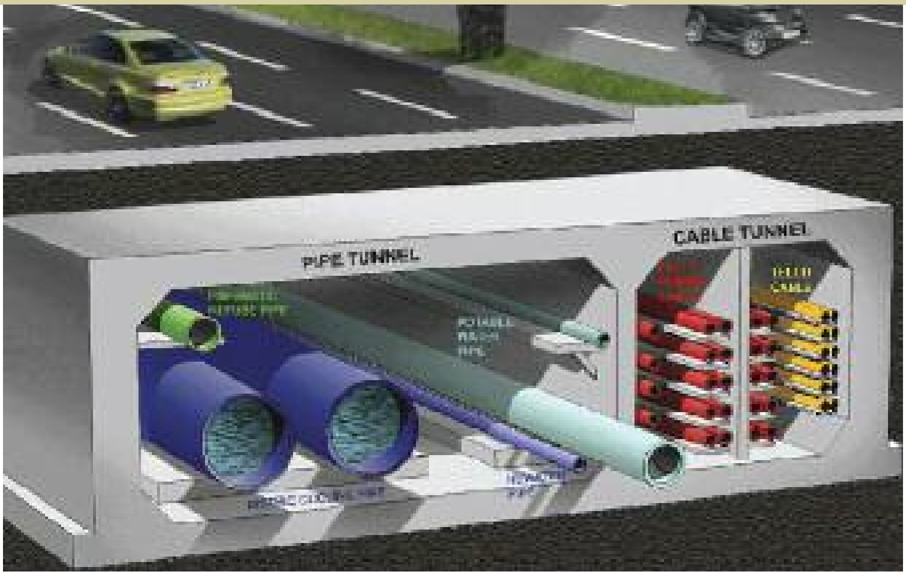
Temporary anchors have a service life of up to two years with reduced corrosion protection. In addition, test anchors are utilized to check anchor capacity and geotechnical condition, while control anchors are used for monitoring purposes.

BBR ground anchors fulfill EN 1537 standards or latest regulations in force at the place of use, and can also be designed as electrically isolated or removable anchors.



Futuristic service supply

PHASES 3A & 3B, COMMON SERVICES TUNNEL, SINGAPORE



Tong Seng Kah and Lee Chong Whey of BBR Holdings, Singapore report that back in December 2007 their company secured its first contract, worth SGD 189.6 million, for Phase 3A of the Common Services Tunnel (CST- 3A) from the Urban Redevelopment Authority (URA). Now, a second contract, worth SGD 139.6 million, has been awarded for the construction of Phase 3B.

CST Phases 3A and 3B involve the construction of a purpose-built tunnel network that will house and distribute various utility services to the 360 hectare waterfront development at Marina Bay including electrical and telecommunication cables, potable water pipes, NEWater (non-potable water), district cooling pipes and a pneumatic refuse conveying system.

SECOND OF ITS KIND

This 20 km tunnel system, running at an average depth of 15 m below ground level, is believed to be only the second of its kind to be constructed – the first is in Japan. The scope of works includes completion of the CST Box Tunnel and backfill at Sheares Avenue and Central Boulevard, as well as sewerage works.

Sandwiched among the other large-scale projects around the region, BBR's wholly-owned subsidiary, Singapore Piling & Civil Engineering is racing to complete the makeover of the Marina Bay region within the next few years.

HIGH WATER TABLE

As the site sits on previously reclaimed land with a high ground water table, construction of any form is demanding, especially when it comes to the provision of sufficient foundations for the structures.

Besides using deep foundation piles, of 50 m and more long, to reach the 'Old Alluvium' layer, advance jet-grouting technology is being deployed on-site – both as soil-improvement, as well as to serve as a waterproofing layer to keep water out of the excavated area.

TEMPORARY EARTH RETAINING SYSTEM

In addition, to make things more difficult, the service tunnel was being constructed using a cut-and-cover approach involving deep excavation of up to 22 m. Hence, construction of a detailed and extensive temporary earth retaining system was necessary to facilitate the excavation.

The basic arrangement involves sheet piles, strengthened with vertical soldier piles, running along the perimeter of the excavation area, supported by horizontal double I-beam struts for every layer that is being excavated. Instruments have been placed at strategic locations within the designated vicinity to monitor any earth movement.

Phase 3A is due for completion in the second half of 2011, while Phase 3B which started in May 2010 is targeted for completion in late 2014.

TEAM & TECHNOLOGY

OWNER Ministry for National Development

MAIN CONTRACTOR
Singapore Piling & Civil Engineering Pte Ltd

MANAGING AGENT
Urban Redevelopment Authority

STRUCTURAL CONSULTANT
AECOM (Singapore) Pte Ltd – (3A)
Parsons Brinckerhoff Pte Ltd – (3B)

BBR NETWORK MEMBER
BBR Holdings (Singapore)

HAYWARDS SUBSTATION, WELLINGTON, NEW ZEALAND

High capacity anchoring

Bojan Radosavljevic of New Zealand-based BBR Contech reports that the team is currently involved in another major Transpower project designed to increase the security of New Zealand's electricity supply.

The 'HVDC Pole 3' project will increase the capacity of the HVDC (high voltage, direct current) link that connects the North and South Island power systems. It involves building new electricity converter stations at Benmore in the Waitaki Valley and Haywards in the Hutt Valley, replacing 45-year old 'Pole 1' equipment. The converter stations are used to convert alternating current (AC) to direct current (DC) at Benmore, which is then transmitted to Haywards and converted back from DC to AC before being injected into the National Grid.

We are working at the Haywards site, installing a series of soil nails and ground anchors in both existing and new retaining structures to strengthen and protect the site against seismic activity. Grade 500 soil nails are being used to strengthen an existing reinforced earth wall, while higher capacity BBR CONA strand anchors are being used for the new structures.

Working with main contractor Brian Perry Civil and Griffiths Drilling, we are installing around 200 anchors at depths of 15-25 m in six different locations. Offering double corrosion protection and a 100-year design life, they can handle load capacities of 450-1,500 kN. The Pole 3 project will increase the capacity of the overall HVDC link to 1,000 MW from 2012 – and to 1,200 MW from 2014. Once Pole 3 has been built, the old Pole 1 will be fully decommissioned and removed.

TEAM & TECHNOLOGY

OWNER Transpower NZ Ltd

MAIN CONTRACTOR Brian Perry Civil

DESIGNER AECOM

ANCHORING CONTRACTOR Griffiths Drilling

TECHNOLOGY BBR CONA ground anchor
Soil nail

BBR NETWORK MEMBER
BBR Contech (New Zealand)

COMBINED HEAT & POWER PLANT, SISAK, CROATIA

Maximizing returns

The new Sisak Block C combined heat and power plant is being built within the existing Sisak power plant, on the right bank of the River Sava, near the city of Sisak in Croatia. Krešimir Bogadi, Operations Department Manager for Croatia-based **BBR Adria,** describes the static pile testing work they undertook for this project.

The first block of this power plant was built in 1970 and the second was constructed in 1976, both blocks have a nominal power output of 210 MW – resulting in a current nominal power output of 420 MW.

The bearing structure for the new turbo gas generator rests on 63 heavy piles, each 18 m long and 0.9 m in diameter. A static pile test to a maximum force of 4,000 kN had been prescribed in the main design. The high force required an anchor construction, consisting of four tensile piles and a steel 'H' shape beam construction, which was used to distribute load from the jack to the tensile piles.

The tensile piles were positioned three meters from the test pile. The steel beam construction was anchored to the tensile piles using four BBR CONA 0706 ground anchors – one on each pile.

A total of five tests were carried out and 5 x 4 BBR CONA 0706 ground anchors were installed. Each test lasted for 15 hours and was under the constant surveillance of the Civil Engineering Institute of Croatia.

It was very important to press ahead and get the tests finished, so that work on other piles could continue – and program time, lost earlier, could be recovered. The BBR Adria team completed the testing in ten days – thus, completely satisfying the customer's requirements.

TEAM & TECHNOLOGY

OWNER Hrvatska Elektroprivreda d.d.

MAIN CONTRACTOR
ING-GRAD d.o.o., Zagreb

DESIGNER Elektroprojekt d.d., Zagreb

TECHNOLOGY
BBR CONA ground anchor

BBR NETWORK MEMBER
BBR Adria d.o.o. (Croatia)

TEMPLE OF DIVINE PROVIDENCE, WARSAW, POLAND

Honoring history

The Temple of Divine Providence in Warsaw's Wilanów district is one of a kind. The building is a huge Greek-type cross on plan with a temple inside. The Temple is topped with a dome that reaches 50 m above ground level. The four sides of the cross are formed by the four so-called 'bridges' which join four huge pylons – 26 m above ground level. Inside the 'bridges', there is a museum dedicated to Pope John Paul II. Bartosz Łukijaniuk and Dariusz Masłowski of BBR Polska provide some background and describe how the complex heavy lifting challenges for this unique project were met.

This construction site and indeed the project itself is quite well-known, as it has been intertwined with the history of Poland, since the end of 18th century – when the very first national constitution in Europe was agreed here on 3rd May 1791. At that time, the Polish government made a resolution to build a temple as an act of thanksgiving for the divine providence which it was believed had been the *spiritus movens* of the constitution. Subsequently, many historical events conspired to prevent the resolution from being fulfilled – that is, until now. The Roman Catholic Church in Poland is now building the Temple of Divine Providence, with financial support from state authorities.

WORK SCOPE OVERVIEW

Our work scope included concept development which started several years ago and was followed by general and detailed design of the lifting operations, in collaboration with structural designers SDS Sp. z o.o. This included all temporary structures for supporting the hydraulic lifting system, working platforms, temporary and permanent supports and bearings. Then, finally, the performing of four complex lifting operations.

THE 'BRIDGES'

Each 'bridge' is a 40 m long single span beam with a 4.8 m high and 4.9 m wide box cross-section – weighing 780 t.

The four 'bridges' are designed to be 26 m above ground level!
Discussion was underway about how this could be achieved and how big the scaffolding would need to be. At this point, BBR Polska proposed using their expertise and know-how to lift them from the ground up to their ultimate destination above. Thus, the 'bridges' were concreted on the ground between pylons – the gap between the 'bridge' and the pylon wall was around 30 mm wide.
Before any works began, very detailed 3-D survey analyses of the pylon walls were prepared by the client. This helped greatly in positioning the bridges correctly during concreting, such that a smooth lifting operation could follow.

ALLOWING FOR RELAXATION

The 'bridges' were constructed on the ground in standard shuttering. It was not possible to lift such a big element straight from the shuttering and fix it to the pylon walls because of relaxation. It is in the element's nature to deflect – and the deflection grows bigger over time, until it reaches a specific level. With such a long 'bridge', any small deflection in the middle of the span would have a huge influence on the end walls – they would tilt towards the middle section of the 'bridge'.
If we fixed unrelaxed 'bridges' to the pylon, during 'bridge' relaxation the tilting end walls would destroy the connection
Therefore, short steel temporary supports were provided to hold the 'bridge' in place, allowing the shuttering to be removed and giving time for appropriate relaxation. The supports were fixed to the pylon walls with PT bars. However, it works not only because of friction between the steel plates and concrete wall – the support was also designed to work as a spur.
Vertical force – load from the 'bridge' – was transferred to the wall by friction force – introduced by PT bars – and bending moment, which gave a horizontal force on the wall. So the steel spur was not supported on anything else, just the wall. Each support was topped with an elastomeric bearing. Each side of the 'bridge' was supported by four such spurs, so each support was loaded with almost 100 t vertical force. Each supported 'bridge' was left for two weeks for relaxation and the deflection of the structure was carefully monitored.

LIFTING SYSTEM

The lifting system was installed at the top of the pylons. We used a four point hydraulic lifting system – four VT SH 1906 strand lifters were supplied along with two BBR Polska

special heavy lifting pumps. The jacks, together with hydraulic gripping heads were controlled, synchronized and operated from the BBR HL-1 control system.
On each 'bridge' end, there were two jacks and one pump. The 'bridge' was lifted by four tendons, each made of 19 compacted seven wire strands. The jacks were installed on a specially designed working platform on top of the pylons. The tendons were fixed to the 'bridge' by a special rudder (connector). Four PT bars were guided though the end wall and stressed. These bars held a thick steel plate – a connector – on which the tendon anchor head was supported.
The lifting system (steel structures and equipment) was designed with a safety factor of more than two – which means that two lifting points alone were able to hold the weight of the 'bridge'. When the first 'bridge' – the north one – was ready for lifting, the lifting system was checked and the weather forecast for the next day was consulted.
With the weather set fair, the next morning, the lifting operation began – and later that night the 'bridge' could be found 26 m above ground level. It had been a very long, but successful day.

MAKING THE CONNECTION

When the 'bridge' was on the correct level, the only remaining task was to connect it with the pylon. This was achieved using a special dowel. The dowel was a stainless steel box, weighing 200 kg, filled with ready mixed high strength mortar. During construction, steel boxes had been placed in the 'bridge' walls, in preparation for dowel installation.
Parts of the pylon walls were not constructed – purposely left for concreting later, at the same time as the 'bridge' connection. When the 'bridge' reached the design level, the dowels were installed in the steel boxes in the 'bridge' end walls and empty spaces were filled with cement grout. Pot bearings were fixed underneath them. The dowels with the bearings were secured in the pylon walls by steel boxes also allowing access for subsequent bearing inspection. Additional reinforcement was installed and the walls were concreted. After the concrete reached its design strength, the tendons still holding the 'bridge' were released and the 'bridge' rested on the bearings.

LOGISTICS

We carried out four lifting operations using two sets of supporting spurs, two sets of lifting system support structures and one set of lifting equipment. While one bridge was lifted and connected, the second one was resting on temporary supports, relaxing before the lifting operation at the same time as we were preparing the structure to support the jacks. All this complex work took 17 weeks – from the installation of temporary supports for the first 'bridge' to loading of the last bridge bearings. Although it may seem that these four lifting operations were repetitive, in fact each lift was slightly different. At the time, we were dealing with the heaviest concrete element ever lifted in Poland – and the project had not just one, but four such elements. This record has not been beaten yet – and we eagerly await our next challenge.

TEAM & TECHNOLOGY

OWNER Metropolitan Curia of Warsaw (Roman Catholic Church Dioceses)
MAIN CONTRACTOR WARBUD S.A
DESIGNER OF HEAVY LIFTING OPERATIONS BBR Polska Sp. z o.o. and SDS Sp. z o.o.
BUILDING DESIGNER Szymborski i Szymborski Architekci (architecture)
FPK NAZBUD mgr inz. Wojciech Naziebb (structure)
TECHNOLOGY Heavy lifting
BBR NETWORK MEMBER BBR Polska Sp. z o.o. (Poland)

PANEL WALLS, POLAND

Reinforced soil structures

Reinforced fill technology has been around for more than 40 years and, over this time, has gained the trust of designers and contractors all around the world says Marcin Harhala of BBR Polska. These structures have gained in popularity due to reliability, competitive price and wide range of application. Globally, over one million square meters of such strengthened structures are built each year.

The desire to implement the new technology and create real competition to existing products on the market have become the main drivers of this development by BBR Polska. The work and the preparations sped up in early 2009, when Marcin Harhala, an engineer specializing in reinforced soil technology, joined the company.

The reinforced soil structure model is based on a complex idea, where galvanized wire mesh is placed at regular distances inside the embankment, forming layers strengthening the ground. The wire mesh is held in place by the friction that develops from contact with the backfill. An embankment which has been reinforced in this way becomes thus a self-supporting structure. A light facing unit, such as concrete panels or steel mesh, forms the surface of the whole system and provides an aesthetic appearance.

To obtain the necessary Technical Approval, we had to carry out several type tests of the components comprising the package for constructing these strengthened soil structures – known as 'Panel Walls'. Having undergone an 11-month process – involving independent testing, then submission of documentation and material samples for official evaluation – in June 2010, we were finally granted Technical Approval by the Roads and Bridge Construction Research Institute.

Barely a month later, we received our first assignment – to build 2,250 m^2 of Panel Walls which would consume over 40 t of reinforcing wire mesh. The structure is located on the E65 Warsaw-Gdynia railway line where improvements are currently underway. The preparatory production work was well-advanced by the time we started work in spring. For this particular contract, we used molds delivering a maximum daily production output of 45 m^2. With two more projects in hand for 2,000 m^2, we are all looking forward to more opportunities to use our new Panel Wall system and, indeed, the success of this new technology.

TEAM & TECHNOLOGY

OWNER PKP-PLK

DESIGNER Centralne Biuro Projektowo-Badawcze Budownictwa Kolejowego „KOLPROJEKT" Sp. z o.o.

MAIN CONTRACTOR Intercor Sp. z o.o.

BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

WIND TOWERS, BREMERHAVEN & HAMBURG, GERMANY

CATCHING THE WIND

Following on from the *'Win-win situation'* feature on wind tower construction in the last edition of *CONNAECT,* Christian Leicht of German BBR Network Member VORSPANN-TECHNIK takes us on a journey through the European wind energy marketplace and gives a brief overview of two projects in Germany.

In 2009, new wind power installations accounted for a staggering 39% of all new energy installations in Europe, it was the second year running that more wind energy installations were created than any other energy technology. Germany and Spain are the undisputed trail-blazers in the adoption of wind power – holding a 34% and 26% share respectively of the entire installed wind energy base in the EU.

WIND TOWER CONSTRUCTION

Basically, three types of construction are common for the wind towers – steel, concrete and a hybrid mixed version. Currently, the hybrid construction method seems to be the most economical for high towers which require thicker walls and tower diameters in the foot.

Since the end of the 1990s, we have been involved in both research and development, as well as the construction of wind towers. So far, we have been contracted for over ten wind park projects and prototypes – and in 2011, we will be carrying out a large project with around 50 wind towers.

CONA CMB BAND PT

CONA CMB bands adapt themselves perfectly to the tower geometry and require very little maintenance, are re-stressable and exchangeable. They are preassembled in the factory (including corrosion protection) and can be installed very quickly on site. Furthermore, they can be mounted all year round, as they don't need grouting which requires special grouting knowledge and equipment due to the heights involved. Recently, using 43 CONA CMB tendons for each one, we constructed two 130 m high prototype wind towers for offshore applications at a test field in Bremerhaven. Meanwhile in Hamburg, we built a further two towers using 18 CONA CMB band tendons in each – these towers are approaching 140 m high and have rotors covering an area larger than a football pitch!

TEAM & TECHNOLOGY

OWNER
Prokon Nord / Hamburg Energy GmbH

MAIN CONTRACTOR
Matthäi Bauunternehmen GmbH & Co. KG / Gebr. Echterhoff GmbH

DESIGNER G+S Planungsgesellschaft mbH / Oevermann GmbH

TECHNOLOGY BBR VT CONA CMB band

BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH (Germany)

Tactics for tricky pylon

PYLON INCLINATION, SOSNICA JUNCTION, GLIWICE, POLAND

Tomasz Jendernal of BBR Polska reports that new Sosnica Junction, in Gliwice, southern Poland, is a milestone in Polish highway infrastructure development – it is the first intersection of two motorways in the country. With a total of 16 bridges and 30 km of road within the junction, it is also deemed to be the largest road junction in Central Europe.

Three roads converge at Sosnica Junction – the A4 motorway, the A1 North-South – part of the priority North-South Trans European corridor linking Scandinavia with the Mediterranean – and the DK44 country road. Both the A4 and the DK44 remain open to traffic while the A1 motorway is under construction.

COMPLEX BRIDGE

One of the most complicated bridges to be constructed was the WD-467a cable-stayed viaduct over the existing A4 motorway. The viaduct has one 45 m high H-shaped pylon to one side of the motorway, a 100 m long main span crossing the motorway and access roads, plus a short 10 m long side span.
A special feature of this viaduct, is that the pylon is inclined 15 degrees towards the main span and seated on fixed spherical bearings allowing rotation only. The main contractor had decided to build the pylon vertically to 32 m above foundation level using climbing scaffolds, then install the 14 m tall steel insert, incline the pylon to its final position and finally cover the steel insert with cast concrete. We were called in to consult on the pylon construction method, to provide the system of stabilizing ties with force measuring devices in temporary stays and to perform the inclination operation.

INCLINATION

For the inclination operation, we supplied special tendons which had a Ultimate Tensile Force (UTF) of over 8,600 kN, allowed rotation on both ends and also extension from 21 m to 25 m during the operation. Two tendons were installed, one on each leg of the pylon. The tendon construction was quite unique. On both ends, there were a pair of forks to allow rotation by the pin connection with fish plates. Fish plates were fixed to the top of the pylon and the bottom

of the abutment using post-tensioning bars, thus creating a shear connection.

The uppermost tendons consisted of a pair of high-tensile 2.8 m long post-tensioning bars which were threaded into the forks by using special adapters. The lower ends of the bars were fixed to a cross-beam with system flat nuts. The 18 m long BBR VT CONA CME external 3106 tendon was fixed to the cross-beam by a conventional A1-head. Wedges were secured in position with springs and the whole A1-head was fixed to the cross-beam by a retaining plate. The lower tendons were again composed of a pair of PT bars. However, in this case the bars were much longer – 6.3 m – and fully-threaded, as they were used to extend the tendon length during inclination. They were fixed in both bottom and intermediate cross-beams.

The tendon extension mechanism comprised a pair of cross-beams and a pair of hydraulic jacks with cylinders between them. To extend the tendons under tensile force, 200 t double-acting hydraulic cylinders with 150 mm stroke were installed in each tendon. Tendons were extended in stages, during each of which their length was increased by 130 mm. The pylon was supported on a hinge installed eccentrically, forcing the pylon to incline by its own weight.

DYNAMIC SHOCK

Everything was going very well until the pylon reached 13.5 degrees from the vertical position – 90% of the target inclination. Suddenly, there was a huge 'bang' – and the tendons started to swing. The operation was immediately halted.

Engineers investigated and discovered that the top fish plate of the left tendon had lost its friction with the pylon and had slipped down by five centimeters, cutting some of fixation bolts. The situation was critical – the pylon was now hanging over a live motorway, supported only by two tendons and, after the dynamic shock, one anchorage was damaged.

Fortunately, there was no damage within the tendons. All components, including strain gauges installed to provide an independent load check of the tendons, had survived and were in good condition. Additional backstays were installed and stressed immediately, releasing the tension in the inclination tendons, so the pylon was stabilized ... but still not in its final position.

SUCCESSFUL SOLUTION

As the position of the pylon was only 1.5 degrees from the target, we proposed that the operation could be safely completed by installing conventional strand heavy lifting jacks in place of permanent stay cables. After detailed checks, our proposal was accepted. We supplied and installed two 19-strand heavy lifting jacks, in place of level four stays, one on each leg of the pylon. The jacks and hydraulic gripping heads were controlled and synchronized by the BBR HL-1 control system for strand jacks.

After installation, additional tendons were stressed to release the original tendons to approximately 50% of their stress and the inclination operation was continued using all four tendons. Once the inclination was completed, stabilizing ties were installed and stressed, allowing work on the pylon to be continued and permanent stay cables to be installed.

Use of fully-threaded post-tensioning bars for short-distance load-handling operations in conjunction with BBR tendons and heavy lifting technology is very efficient, fast and safe. Simple hydraulic control systems can, in many cases, be used with the same efficiency as computerized control systems.

TEAM & TECHNOLOGY

OWNER General Directorate for National Roads and Motorways, Katowice Division

MAIN CONTRACTOR J&P – AVAX S.A.

STRUCTURAL DESIGNER
Mosty Katowice Sp. z o. o.
Firma Inzynierska G-F Mosty (erection method)

TECHNOLOGY BBR VT CONA CME external PT bar
Heavy lifting

BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

EMERGENCY REPAIRS, A45 MOTORWAY, GERMANY

Band tendons for bridges

Enormous damage to a number of large bridges on the A45 federal motorway – known as the *Sauerlandlinie* – has necessitated an emergency repairs program. Seven bridge structures need to be strengthened by installing external prestressing. Three large bridges will be reinforced with BBR VT CONA CMB external band tendons, taking advantage of the technical benefits this prestressing method offers. Dipl.-Ing. Thomas Weber of Munich-based BBR Network Member, VORSPANN-TECHNIK describes these external prestressing projects.

The A45 federal motorway runs from Dortmund to Aschaffenburg and most of it was built between 1963 and 1973. The topography dictated the construction of a total of 73 viaducts along the motorway's 257 km length – for this reason, the A45 motorway is also called 'The Queen of Motorways'. The numerous large bridges were built using the most varied of construction methods that were known or newly-developed at the time.

LIMIT FOR DAMAGED BRIDGES

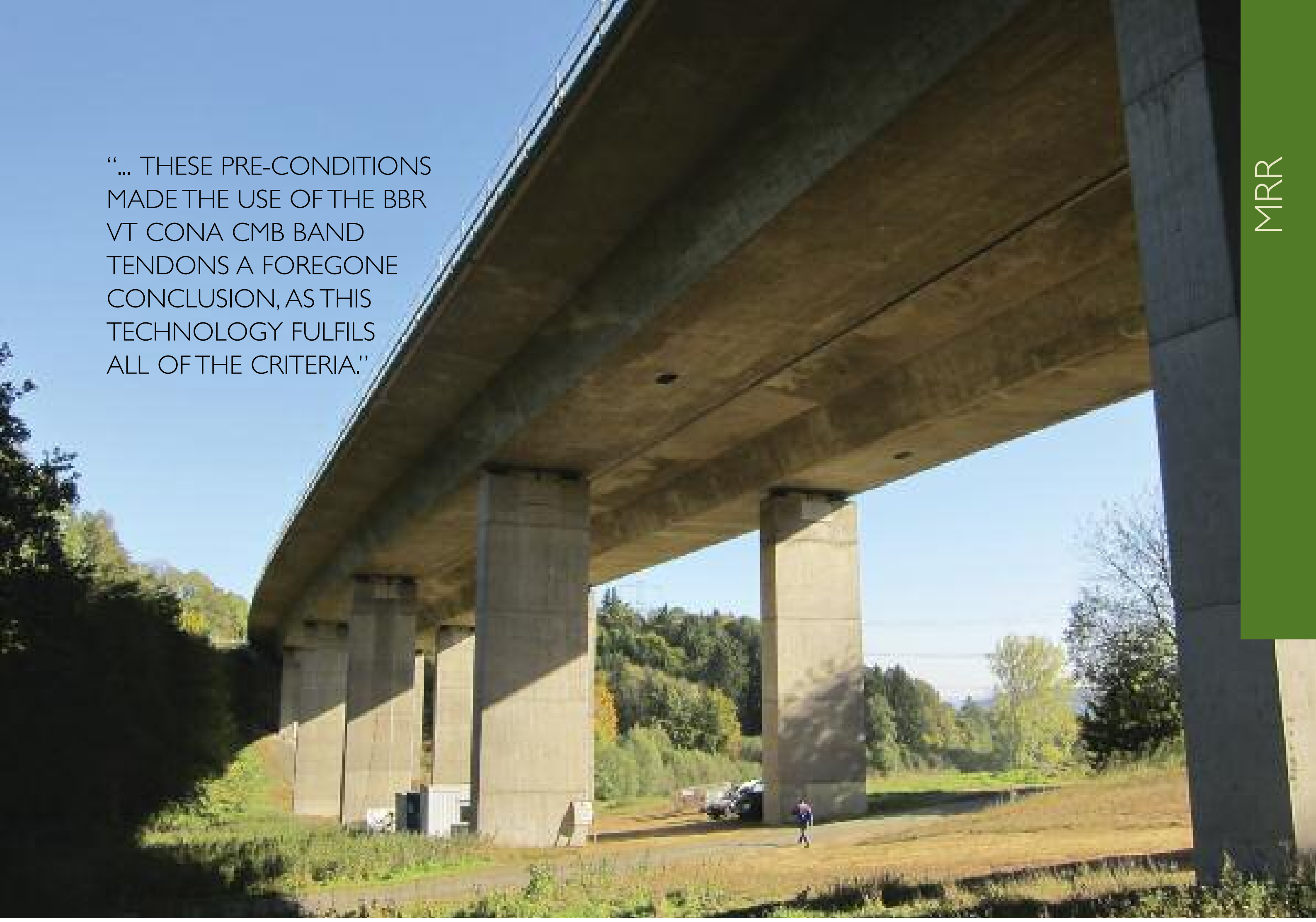
The damage to the bridges led to the imposition of a 60 km/h speed limit for heavy goods vehicles on several of them at the beginning of 2009. Furthermore, the motorway has been declared 'off limits' for the transportation of heavy loads and hazardous materials, as well as for heavy goods vehicles weighing more than 44 t. Eleven large bridges are currently undergoing emergency repairs to ensure their continued use for the next ten years – by that time, they will all have been replaced by new structures.

STRENGTHENING WITH BAND TENDONS

External BBR VT CONA CMB 1606-150 1770 band tendons will be installed on the large Marbachtal, Lützelbachtal und Kreuzbachtal bridges. For structural reasons, intermediate anchoring of the external tendons was ruled out for all three bridges. The client did not want intermediate couplings to be used. In combination with bridge lengths of between 245 m and 400 m, these pre-conditions made the use of the BBR VT CONA CMB band tendons a foregone conclusion, as this technology fulfils all of the criteria.

MARBACHTAL VIADUCT

The 388 m Marbachtal Viaduct, near Dillenburg, is the longest of the three bridges. Only one of the two superstructures is to be strengthened. In each carriageway direction, the superstructure consists of a single compartment box girder with a construction



"... THESE PRE-CONDITIONS MADE THE USE OF THE BBR VT CONA CMB BAND TENDONS A FOREGONE CONCLUSION, AS THIS TECHNOLOGY FULFILS ALL OF THE CRITERIA."

height of 3.5 m. The superstructure carrying the Giessen-bound carriageway will be reinforced with a total of four external BBR VT CONA CMB 1606-150 1770 band tendons. Due to the curvature of the bridge, the deflection of the tendons is mainly horizontal. The tendons are all 385 m long and the tensioning force will be approximately 3 MN. The tendons will be anchored in newly-constructed concreted anchor blocks positioned about two meters from each of the end cross-members.

LÜTZELBACHTAL VIADUCT

The Lützelbachtal Viaduct is about a kilometer from the Marbachtal Viaduct and, in this case, both of the superstructures need strengthening. As described above, four external tendons of the same type will be installed on each superstructure. Anchoring is also achieved by casting new concrete anchor blocks beyond the end cross-members. For this viaduct, the tendons are 248 m long and no vertical deflection is planned.

KREUZBACHTAL VIADUCT

The Kreuzbachtal Viaduct is located further south and, at approximately 245 m long, it is the shortest of the three viaducts. As in the case of the Kreuzbachtal Viaduct, both of the superstructures will be strengthened with four tendons each, the tendons being anchored behind the existing-cross members. These will be pretensioned using special VT 4000 tensioning jacks in the abutment compartment which offers very little space.

TEAM & TECHNOLOGY

OWNER Bundesland Hessen, Amt für Straßen- und Verkehrswesen

MAIN CONTRACTOR
HBS Hörnig Bauwerkssanierung GmbH (Marbachtal Viaduct),
BWS Rhein-Neckar GmbH (Lützelbachtal Viaduct)
Eurovia Beton GmbH, NL Bauwerksinstandsetzung (Kreuzbachtal Viaduct)

DESIGNER
Leonhardt, Andrä und Partner GmbH, Stuttgart (Marbachtal Viaduct & Lützelbachtal Viaduct)
EFG Beratende Ingenieure GmbH, Fuldabrück (Kreuzbachtal Viaduct)

INSPECTING ENGINEER
Dipl.-Ing. Josef Steiner (Lützelbachtal Viaduct),
Prof. Dr.-Ing. Habil. Peter Mark (Marbachtal Viaduct und Kreuzbachtal Viaduct)

TECHNOLOGY BBR VT CONA CMB band

BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH (Germany)

Staff car park girders, Siedlce

EXTERNAL STRENGTHENING, POLAND

‘Active’ structural strength

External tendons strengthen and increase the load capacity of a structure and their effect comes into play immediately after they are stressed – hence the technology often being called ‘active’ strengthening. Project manager Bartosz Łukijaniuk of BBR Polska describes the technology and four such projects recently completed by his company.

The advantages of ‘active’ strengthening are perhaps better appreciated when ‘passive’ strengthening is also understood. ‘Passive’ strengthening takes the form of additional elements fixed to the structure, such as steel profiles being fixed to a girder – these only start their strengthening work when the girder deflects.

External tendons used for strengthening are made of the same type of strands, anchorages and ducts as for newly-built structures. Knowledge of tendon system options is very important, as every structure to be strengthened is different – so for each project, the construction details of tendons may be slightly different. The right PT Specialist, such as one of the BBR Network Member companies, can help to specify and install the appropriate system. For details regarding external tendons, please refer to the European Technical Approvals that describe the BBR VT CONA CME external post-tensioning system.

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1 FACTORY ROOF GIRDERS, PABIANICE

At a 1960s **light bulb factory** in Pabianice, central Poland, managers discovered that, in two production buildings, roof girders were deflecting too much.

Each roof consists of 21 girders made of 30 m long steel trusses supported on concrete columns. The inside of the top chord was concreted to connect the truss and the prefabricated concrete roof surface. The bottom chord was tensioned with three tendons made of 12.5 mm diameter strands. Expert opinion was that the old tendons had lost their stressing force because of corrosion and that 19 of the girders needed strengthening.

The main condition surrounding our work was that the factory should not stop production for more than a few days. So, we devised a special solution using external tendons. Our design required only small additional elements – anchorage blocks and deviators – to be welded to the girders. To allow the owner to monitor the structure in the future, each tendon was equipped with a force sensor, installed in the anchorage. For this project, strands covered with PE sheath filled with anti-corrosion grease were used. Each girder was strengthened with four 150 mm^2 strands (1,860 MPa) – two strands on each side of the girder. There was no access from behind to live tendon anchorages, so we created special

Light bulb factory, Pabianice

anchorage blocks using stressing bars anchored to the girder. During stressing operations, we pulled the bars and the tendons were stressed indirectly. It was extremely important to stress the tendons evenly on both sides of the girder. In total, we used 6.5 t of stressing steel and 126 m of stressing bars.The only time factory production was halted was for stressing operations – lasting a total of three days.

2 STAFF CAR PARK GIRDERS, SIEDLCE

A two level **staff car park** was under construction as part of extension work at Polimex-Mostostal's production plant in Siedlce, eastern Poland. It had three rows of 16 m long steel girders supported on steel columns which were joined with a 100 mm thick concrete slab using steel mandrels. During the slab pour, a detailed survey showed that the girders deflected too much and that the actual slab thickness was 160 mm – 60 mm more than designed. After further examination, expert opinion was that the steel quality did not comply with the specification. The girders had been designed for steel with a tensile strength of 355 MPa, but in fact the girders produced were only of 275 MPa steel – 22% lower than the design. Thirteen girders were affected and they all needed strengthening. We were contracted to elaborate a strengthening solution and then to deliver, install, stress and grout the tendons. The girders were strengthened using four-strand tendons which were installed under the steel girder. The stressing force for each girder was calculated individually – taking into account the actual deflection. Corrosion protection was assured as the strands were covered with PE sheaths filled with anti-corrosion grease and all four strands were guided through an HDPE pipe filled with cement grout.

3 SEWAGE PLANT TANKS, WARSAW

When three concrete tanks in Warsaw's **'South' sewage plant** were leaking, external strengthening and renovation of the walls was prescribed to keep the tanks in working order. Cracks had been appearing – hence the leakage – despite having been injected with epoxy polymers just a few years before. We were invited, together with SDS, to design the external stressing solution.

"KNOWLEDGE OF TENDON SYSTEM OPTIONS IS VERY IMPORTANT, AS EVERY STRUCTURE TO BE STRENGTHENED IS DIFFERENT HERE"

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All three tanks are cube-shaped and are linked together with other chambers, tanks and bypasses. We used circular tendons and because of the shape of the tanks, it was only possible to use straight single strands anchored in steel blocks fixed to the corners of the tanks.

The project was very complicated. We designed nine different types of anchored blocks – 136 blocks were installed and 60 of these were fixed with stressing bars. The installation of the stressing system included boring 774 holes in concrete walls – these were needed for the PT bars and guiding the strands.

To protect against corrosion, we used strands with a grease-filled PE sheath and grouted the PT bars with cement. Meanwhile, 'barrels' and bar nuts were covered with protection cups filled with anti-corrosion grease and the steel anchor blocks were galvanized and covered with epoxy based paint.

In total, we used 9.5 t of strand, cut into 345 monostrand lengths of between 18-37 m and 91 m of bars cut into 126 individual bars of between 0.3-0.6 m long.

4 SPORTS HALL ROOF GIRDERS, GDANSK

Built in 1972 as a roofed hockey pitch, the 5,000-seat **Olivia Sports Hall** in Gdansk is an important building in Polish contemporary history. It was here that, in 1981, the Trade Union 'Solidarnosc' – 'Solidarity', the first independent self-governing trade union in Poland – met to prepare its political manifesto.

The owner wanted to renovate and partially change the roof form to make it less prone to snow accumulation and attendant loading. The roof structure consisted of 10 girders. These were 80 m long, three-dimensional steel trusses with existing asphalt-grouted post-tensioned bottom chords. During →

renovation work, it was discovered that some of the old PT tendons were partially corroded – in areas where anti-corrosion asphalt had not been injected. The owner decided to replace the old tendons with new ones. Accordingly, we prepared a conceptual design and were subsequently contracted for this challenging project.

A decision was taken to strengthen nine girders – requiring a total of 18 tendons. We used 14-strand tendons on each bottom chord profile. To avoid excessive stressing force in the trusses, we had to cut the existing tendons in four places. Without roof surface layers or stressing tendons, the girder could carry its own weight, so the main contractor decided that additional supports would not be needed during tendon replacement operations.

It was a three stage process, with three girders – six tendons – in each stage. The selection of girders, where existing tendons would be cut, was made in such a way that the two girders either side would still have 100% stressing force and would support the unstressed girder. After stressing the new girder tendons in one stage, existing girder tendons relating to the next stage could be cut.

The strands are protected against corrosion by grease-filled HDPE sheaths and were guided though HDPE pipe. The anchor heads are protected by steel caps filled with anti-corrosion grease.

External 'active' tendons, together with 'passive' elements such as FRP materials and stressing bars, are complementary technologies with which we are able strengthen any type of structure. Our MRR department, along with many structures in Poland, is growing in strength! ●

TEAMS & TECHNOLOGIES

1 2 3 4

TECHNOLOGY
BBR VT CONA CME external

BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

1 **LIGHT BULB FACTORY**

OWNER Philips Lighting Poland S.A.
MAIN CONTRACTOR
Mostostal Warszawa S.A.
DESIGNER BBR Polska Sp. z o.o. + SDS Sp. z o.o.

2 **STAFF CAR PARK**

OWNER Polimex-Mostostal S.A
MAIN CONTRACTOR
Polimex-Mostostal S.A.
DESIGNER BBR Polska Sp. z o.o. + SDS Sp. z o.o.

3 **'SOUTH' SEWAGE PLANT**

OWNER 'South' Sewage Plant, Warsaw
MAIN CONTRACTOR Mador Sp. z o.o.
DESIGNER SDS Sp. z o.o.

4 **OLIVIA SPORTS HALL**

OWNER Gdansk Sports Club 'Stoczniowiec'
MAIN CONTRACTOR Ekoinbud Sp. z o.o.
DESIGNER BBR Polska Sp. z o.o. + SDS Sp. z o.o.

Soaring high above surrounding buildings of the TECOM area of Dubai is the I-Rise Tower, a 36-level corporate and retail project – the largest of its kind in the region. During the construction phase, a number of slabs in the car park area had deflected and were in need of rectification. Nour Nwiran of NASA Structural Systems LLC – the BBR Network Member in the United Arab Emirates – reports on how they were able to use their specialist expertise to assist in the hydraulic jacking and CFRP strengthening of the slabs.

Construction of the iconic tower complex by main contractor Al Naboodah Contracting LLC began in November 2007. A number of slabs within the lower floors of the structure were found to have deflected and head consultant for the

SINGRAULI SUPER THERMAL POWER STATION, UTTAR PRADESH, INDIA

Big push for power

The country's largest power producer had a critical issue in one of their 22 thermal power stations. Mr J Gopinath of BBR (India) Pvt. Ltd tells how it was resolved while still allowing the power plant to continue operations.

At Shakthinagar in Utar Pradesh, National Thermal Power Corporation Ltd's 28-year old Singrauli super thermal power station had a problem when the track hopper in the coal handling unit went critical – a section of the plough table, from where coal is fed onto the conveyors, had become tilted.

The 200 m long concrete plough table is around 3.1 m wide and supported by 50 columns, located at 4 m intervals and with an expansion joint every ten columns. A section of the plough table, between columns 30 and 40, had developed a tilt of around 100 to 150 mm at the top due to concrete

I-RISE TOWER,
DUBAI, UNITED ARAB EMIRATES

Rising above the challenge

project, Khatib & Alami, undertook an assessment and detailed a design for remediation and strengthening works.

OUR APPROACH

We were contracted by the main contractor to undertake the remedial strengthening works to the four levels of the car park area. Our approach was to use hydraulic jacking to lift two slabs at the same time – lifting both levels simultaneously helped greatly in finishing the work within the project's tight time constraints. To achieve the desired results, extremely dense propping was placed between the first two levels to be lifted, effectively making them move as one.

SLAB LIFTING & STRENGTHENING

Slab lifting was achieved by using hydraulic bottle jacks placed on steel 'stools' and beams to ensure point loading was minimized. Once lifted into the correct position, the slabs were appropriately propped and CFRP strengthening applied. Preparation of the slab areas was completed by sand blasting and CFRP laminate strips were installed to the soffits of the four levels, in accordance with the consultant's design.

In excess of 1,100 linear meters of CFRP laminates were installed on the soffits of the four car park levels and we successfully completed the works within the tight time frame, ensuring the slabs remained in their new position and allowing other works to the area to continue without delay.

TEAM & TECHNOLOGY

OWNER Realty Capital Middle East FZ-LLC
MAIN CONTRACTOR Al Naboodah Contracting Co. LLC, Dubai
DESIGNER Khatib & Alami, Sharjah
TECHNOLOGY Heavy lifting MRR range
BBR NETWORK MEMBER Structural Systems LLC (United Arab Emirates)

deterioration at the column bases, resulting from the quality and age of the concrete.

TWO STAGE SCHEME

The scheme consisted of two stages – the first was to push all tilted columns using horizontally placed hydraulic jacks and then, secondly, to strengthen the columns by jacketing with high strength micro-concrete. A structural steel frame system with struts and vertical supports was fabricated, erected and braced – forming a framework around each column.

JACKING OPERATION

All columns in a single unit of the plough table – that is, between expansion joints – were fitted with jacks. A total of 11 jacks abutting the columns were kept in position, touching the column faces. Five jacks were connected with one hydraulic pump and the remaining six jacks were connected to another pump.

Dial gauges were fixed at the top of each column to observe the movement during jacking. A detailed check list was prepared and, after ensuring all things were in order, both pumps were operated simultaneously. The ram reading of each jack and dial gauge readings were noted for each 10 mm movement and the operation was continued until all columns were completely vertical.

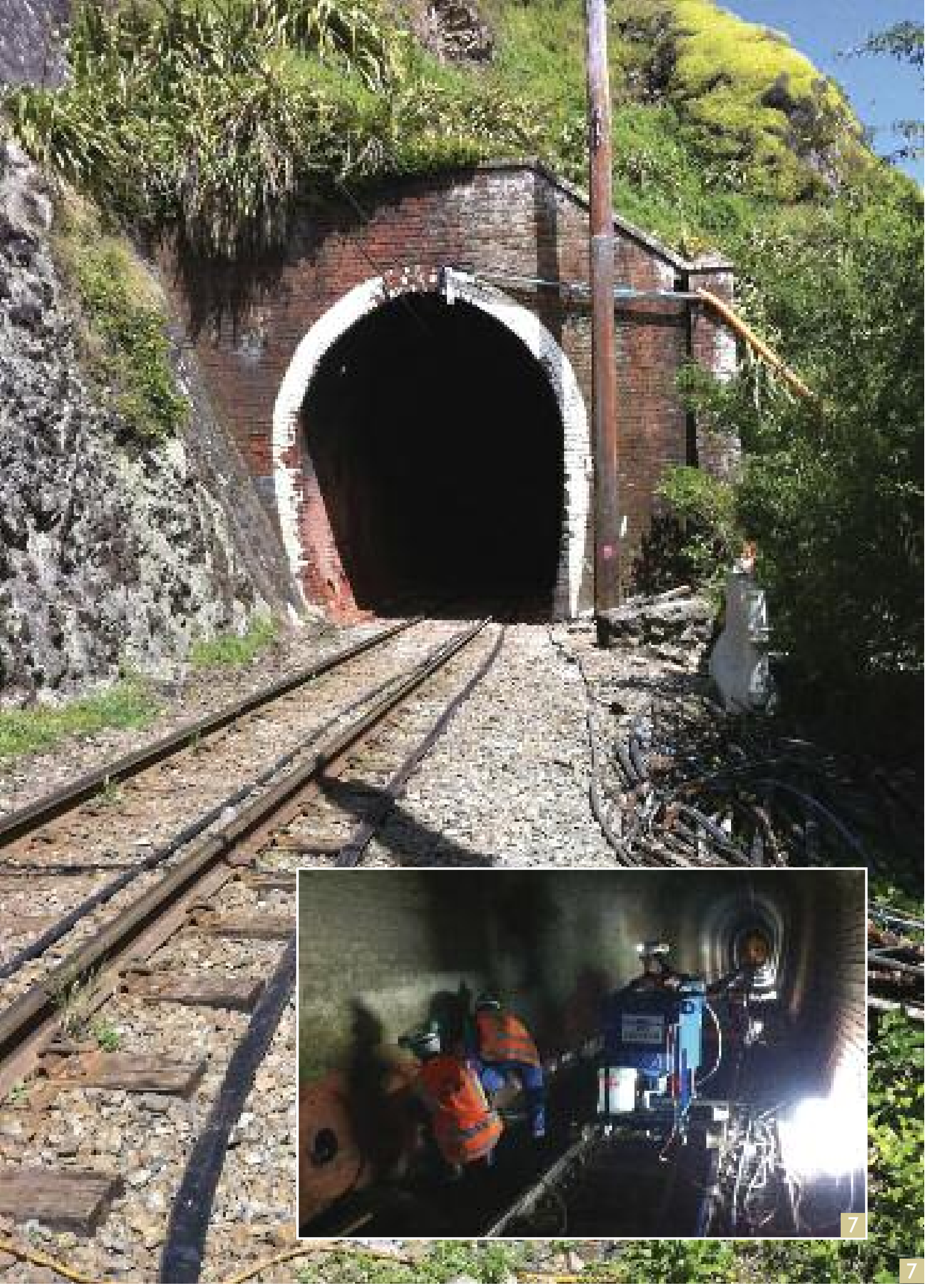
COLUMN STRENGTHENING

With the steel struts and jacks still in position, we repaired and strengthened the columns. We chipped out the deteriorated cover concrete and applied an anti-corrosive epoxy paint to the now-exposed existing reinforcement. Shear connectors were fixed to the column and additional reinforcement was applied. High strength micro-concrete was then poured after erecting formwork, thus the column sizes were increased to 550 x 650 mm – from an original size of 250 x 350 mm.

Although it only took three months, the whole operation was carried out with the greatest of care to avoid any damage to the existing structure – and we were rewarded with an entirely satisfied client.

TEAM & TECHNOLOGY

OWNER National Thermal Power Corporate Ltd
MAIN CONTRACTOR BBR (India)
DESIGNER BBR (India)
TECHNOLOGY Heavy lifting MRR range
BBR NETWORK MEMBER BBR (India) Pvt. Ltd



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KIWI RAIL NETWORK UPGRADING, NEW ZEALAND

Railway renovations

Since the Government returned the rail network to public sector ownership in 2008, it has earmarked more than NZ$ 1.5 billion for upgrading and improvements. Peter Higgins, Southern Regional Manager of New Zealand-based BBR Contech, reports on the role his company has been playing in this major program.

We have provided a range of specialist post-tensioning and MRR services to Kiwi Rail – both as main contractor or as a specialist subcontractor supporting larger projects. Services have included supply and installation of post-tensioning materials and stressing services, grouting, ground anchoring, FRP strengthening and shotcreting.

1 ANCHORS AWAY, WELLINGTON

Mackays Crossing is a substantial project north of Wellington where we have installed 25 50 mm diameter high capacity bar ground anchors as part of a soldier pile retention wall. Each anchor is up to 18 m long with a capacity of 2,000 kN. Further up the track, the team has also built a 150 mm thick sprayed concrete retaining wall, complete with 20 ground anchors made of 32 mm stressing grade bar.

2 PT PILE CAPS & PRECAST, SOUTH ISLAND

The **Arahura Bridge** was a single-lane combined road and rail timber truss bridge, built in 1893 on the remote and rugged West Coast of the South Island. At more than 120 years old, the bridge was near the end of its serviceable life and due for replacement.

The new bridge was built in stages to ensure that the state highway remained open throughout the two-year construction period. The new 220 m long bridge consists of nine steel and concrete spans.

The BBR CONA multi-strand system was specified for the 140 19-strand draped pile cap tendons and 45 19-strand transverse tendons.

3 NEW FOR OLD, MAHENO

Part of the Main South Line, near Maheno in North Otago, **Bridge 167** was originally built with timber piers. The modernization and strengthening project involved removing the existing steel spars and timber piers and replacing the piers with new concrete piles and precast concrete cross-beams. We were commissioned to supply 40 mm stress bars for the work, then stress and grout the precast concrete cross-beams onto the piles.

4 STRESS BAR & PT, DUNEDIN

We were engaged for stress bar supply and post-tensioning services for the renewal project at **Bridge 217** near Dunedin. Four 40 mm diameter stress bars were cast vertically into each of six new piles, leaving 1,000 mm of bar exposed at the top. The new precast pier caps were lowered into position over the bars and post-tensioned to lock the pier caps into place.

3

5 SUPPLY & STRESSING, SOUTH ISLAND

Originally constructed in 1937, **Bridge 89** is a 16-span steel plate girder bridge on the South Island. The underpinning of Piers 6 & 7 involved two new bored piles either side of the existing pier with new pile caps formed around the existing pier and post-tensioned with a BBR CONA 1905 tendon each side and external to the existing pier linking the two new pile caps. We supplied the post-tensioning duct, BBR CONA 1905 anchorages and antiburst spirals and later stressed the 7.5 m long tendons to achieve 70% tensile strength after transfer.

6 TRENCH WALLS, AUCKLAND

Part of the Western Line railway in Auckland, the **New Lynn Rail Trench** project – which eliminates two busy level crossings and adds two brand new bridges – involved constructing approximately 1 km of rail trench up to 8 m deep with a new central


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island platform. The trench walls were constructed as diaphragm walls with every third panel founding on rock at depths of up to 35 m. We were engaged to apply gunite between secant piles of the trench walls to reinstate and patch isolated areas following full excavation of the trench.

7 TUNNEL WALL STRENGTHENING, WELLINGTON

Among the improvements tabled within the Wellington Region Rail Program was a lowering of the track level and widening the tunnel sides of the seven **Johnsonville Rail Tunnels** to allow more modern trains to pass through.

We were awarded the contract for strengthening the walls in readiness for the floors to be lowered. Strengthening methods included injection of grout through the brick tunnel lining to fill voids present in the area between the brick and the rock – known as the contact zone – and installation of rockbolts below springline level. A total of approximately 300 m^3 of specially formulated cementitious grout was injected into voids and rock bolting was carried out under a separate contract following completion of the grouting. All work was carried out during night shift operations with the railway system required to be opened and fully operational each working day for normal commuter rail services.

In mid-2010, we were awarded a further contract for similar work on the North-South Junction line just north of Wellington – comprising another four tunnels ranging in length from 100 m to 350 m. A similar volume of void grouting is required and a total of approximately 1,800 rock bolts. ●

TEAMS & TECHNOLOGIES

1 2 3 4 5 6 7

OWNER Kiwi Rail
BBR NETWORK MEMBER
BBR Contech (New Zealand)

1 MACKAYS CROSSING
MAIN CONTRACTOR Downer (Rail Division)
DESIGNER Opus International Consultants
TECHNOLOGY Bar ground anchor

2 ARAHURA BRIDGE
MAIN CONTRACTOR HEB Structures
DESIGNER ONTRACK Structures Engineering
TECHNOLOGY BBR CONA internal

3 BRIDGE 167
MAIN CONTRACTOR Brian Perry Civil
DESIGNER ONTRACK Structures Engineering
TECHNOLOGY PT bar

4 BRIDGE 217
MAIN CONTRACTOR Southroads Ltd
DESIGNER ONTRACK Structures Engineering
TECHNOLOGY PT bar

5 BRIDGE 89
MAIN CONTRACTOR
Smith Crane & Construction Ltd
DESIGNER ONTRACK Structures Engineering
TECHNOLOGY BBR CONA external

6 NEW LYNN RAIL TRENCH
MAIN CONTRACTOR
Fletcher Construction Limited
DESIGNER ONTRACK Structures Engineering
TECHNOLOGY MRR range

7 JOHNSONVILLE RAIL TUNNELS
MAIN CONTRACTOR
BBR Contech (New Zealand)
DESIGNER Parsons Brinckerhoff / Beca
TECHNOLOGY MRR range

BARBARON VILLA, MAHÉ, SEYCHELLES

Paradise restored

Set on one of the many picturesque peaks of Mahé Island in the Seychelles, the Barbaron Villa is a private retreat being developed for the royal family of the United Arab Emirates. This epic development – in an area defined by its natural beauty – was the subject of design deficiencies and in need of a swift, yet reliable strengthening process. Nour Nwiran of NASA Structural Systems LLC – the BBR Network Member based in the United Arab Emirates – reports on how they set about the challenge of restoring paradise.

The Barbaron Villa development consists of four palace-style villas – the Main Villa, Swimming Pool Villa, VIP Villa and VVIP Villa. Construction was being managed by the Department of the President's Affairs (DOPA) in Abu Dhabi which engaged main contractor ASCON to take possession of the project from others who had initiated its design and construction. In conjunction with newly-appointed consultant Planquadrat Middle East (PQME), they identified design deficiencies in a vast number of structural members within the Swimming Pool and Main Villas.

SWIFT SOLUTION

Construction of the villas was well-advanced and it was clear that a speedy solution – offering minimal disruption to existing mechanical, electrical and plumbing (MEP) work and finishes – was required to ensure timely project completion. With our in-house FRP design team, we were able to provide a CFRP solution for the strengthening works.

DESIGN ASPECTS

It was inevitable that the CFRP strengthening design would have to be completed at a blistering pace in order to minimize the ongoing effect of the works.
The majority of the design related to the 13-bedroom guest Swimming Pool Villa which required strengthening to over 50 reinforced concrete beams and slabs using CFRP laminate, CFRP sheet and CFRP shear plates. By comparison, the design of the Main Villa CFRP strengthening works proved to be much less of a challenge.

PLANNING & PREPARATION

All staff, materials and equipment were brought into the Seychelles from the United Arab Emirates and DOPA's ongoing construction of the remaining villas was facilitated by daily cargo flights of plant and materials specifically for the works. Through good initial planning, we ensured that the correct amount of plant and materials was delivered.
Preparation to all reinforced concrete members was completed by surface grinding to achieve the etched surface finish required for application of CFRP materials.

Project benefits with CFRP

- No bulky material – lightweight and easy-to-handle material in delicate situations.
- No corrosion issues.
- Existing member sizes remained essentially unchanged.
- Curing time reduced dramatically compared to conventional options.
- Installation completed with minimal disruption to existing finishes

INSTALLATION

CFRP laminate strips were cut to desired lengths using abrasive cutting discs to ensure a clean cut was produced and cleaned with a solvent primer before applying the epoxy-based adhesive. The extreme humidity meant that the adhesive began setting within 15-20 minutes of mixing – swift installation was required to minimize wastage.

Using much the same method, CFRP shear plates were installed to increase the shear capacity of beams in the Swimming Pool Villa. These were 90 degree 'L' shaped plates, cut on site to fit existing beam dimensions. One piece was installed on each side of the beam, with an overlapping section on the soffit of the beam. The plates were anchored by a transverse strip of CFRP sheet crossing the top of each shear plate.

CFRP sheet wrapping, as opposed to CFRP shear plates, was utilized to offer strengthening to additional beams which had been identified as requiring shear strengthening late in the process. During each stage of installation, CFRP test samples were setup for testing with an adhesion tester once curing had been completed.

In total, we supplied and installed:

- 2,500 linear meters of CFRP laminates to beams and slabs
- 800+ CFRP shear plates to beams (Swimming Pool Villa)
- 250 m^2 of CFRP sheet for wrapping beams.

We completed our work to the highest quality standard and in minimal time, ensuring the Barbaron Villa development remained on program.

TEAM & TECHNOLOGY

OWNER United Arab Emirates Royal Family, Abu Dhabi, UAE

MAIN CONTRACTOR Associated Construction & Investments Company LLC (ASCON), Dubai, UAE

DESIGNER NASA Structural Systems LLC

TECHNOLOGY MRR range

BBR NETWORK MEMBER NASA Structural Systems LLC (United Arab Emirates)

CATHODIC PROTECTION, CENTRAL EXPRESSWAY, SINGAPORE

Economic concrete repairs

Foo Shi Min and Lee Chong Whey of BBR Construction Systems, the BBR Network Member in Singapore, report that an Impressed Current Cathodic Protection (ICCP) system has been installed to control corrosion on a section of the Central Expressway (CTE) under the Singapore River. There had been significant water seepage problems and pieces of concrete had fallen from the ceiling of the southbound tunnel.

The ICCP system was installed to protect the tunnel ceiling slab reinforcement against corrosion. First, a trial application was made on a 200 m^2 area of tunnel slab and, then after a six month monitoring period, full implementation – covering 6,000 m^2 of slabs – was undertaken. Regular monitoring now ensures that satisfactory performance is maintained.

The anode system was installed as a number of independent anode zones, which will be positively powered by an independently-controlled output from a transformer rectifier. Power cables will be connected to anodes and reinforcements to allow a current supply from the transformer rectifier to the cathodic protection areas. The performance of the ICCP system will then be monitored by embedded Ag/AgCl reference electrodes, with additional reference electrodes provided at two adjacent slabs to compare the steel condition within and outside of the cathodically protected area.

Based on the data collected over the last few months, the ICCP system has been proven to offer considerable cost savings for long-term repair when compared with the 1980s solution of reconstruction or massive replacement of mechanically sound but chloride-contaminated concrete.

TEAM & TECHNOLOGY

OWNER Land Transport Authority (LTA)

MAIN CONTRACTOR Singapore Piling & Civil Engineering Pte Ltd

TECHNOLOGY MRR range

BBR NETWORK MEMBER BBR Construction Systems Pte Ltd (Singapore)

HORSESHOE BRIDGE STRENGTHENING PROJECT, PERTH, AUSTRALIA

Doubling directions

Stuart Crole of Structural Systems – the BBR Network Member in Australia – reports that his company was awarded the contract to strengthen William Street's Horseshoe Bridge in Perth, by the Main Roads Department of Western Australia.

The original bridge was built in 1903 to provide a connection for vehicle and tram traffic over the railway between Newcastle and Wellington Street in Perth and was operated predominately as a one way traffic system.

CONSTRUCTION BACKGROUND

The original superstructure was a composite deck consisting of steel girder and profiled steel soffit or 'lost formwork' – both imported from England especially for the project. 'Coke breeze' a lightweight fill material was placed on top of the profiled steel sections to a depth of around 400 mm. Over the years, a number of modifications had been carried out to the structure including replacing the top 100 mm of the deck with concrete to improve the strength and waterproofing properties of the bridge superstructure.

BACK TO BASICS

The 21-week contract involved the complete removal of the existing paving, road surface and concrete topping, down to the top of the original profiled steel soffit. The removal work was carried out at night using heavy duty road profiling machines capable of removing 30 m^3/hr – with final trim achieved by a combination of smaller profile machines and hand operated jackhammers.

STRENGTHENING WORK

We replaced the material removed with a 40 MPa fiber-reinforced concrete which was then overlaid with a waterproofing membrane. Bluestone kerbing was laid in accordance with the heritage precinct requirements of Perth City Council and then asphalt to a depth of 50 mm was placed in the vehicle traffic areas and brick paving in the pedestrian areas on either side. Final works also involved the installation of bollards for pedestrian protection and reinstatement of bridge lighting and intersections at either end.

TWO-WAY TRAFFIC

The finished bridge now accommodates a two-way traffic system with one lane in either direction – and provides a greatly improved transport link between Northbridge and the Perth Central Business District.

TEAM & TECHNOLOGY

OWNER Main Roads Western Australia

MAIN CONTRACTOR
Structural Systems

TECHNOLOGY MRR range

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

BBR BALANCED CANTILEVER CONSTRUCTION

Balancing the advantages

The proven and safe balanced cantilever method, as used by the BBR Network, is often appropriate and cost-effective for the construction of long span concrete bridges including various landmark structures where height, topography or geotechnical conditions render the use of conventional formwork uneconomical. In this edition of *CONNÆCT,* we present details of balanced cantilever methodology, an overview of some of the bridges constructed by the BBR Network around the globe using this technique – as well as a special feature on balanced cantilever bridges recently constructed in Poland. →

Safe and Sure technique

Balanced cantilever is one of the most popular bridge construction methods used by BBR Network Members on all continents. The economical range of span lengths for cast-in-situ cantilever construction begins at roughly 70 m and extends to beyond 250 m. Considerable savings can be achieved by using this method rather than conventional bridge construction.

Balanced cantilever construction is one of the five major techniques used when building a bridge. The other methods are conventional falsework, advanced shoring, launching and heavy lifting, in addition to a wide range of different or adapted methods – a more detailed review of these is presented in the fourth edition of CONNAECT.

HISTORY

The first application of cast-in-situ reinforced concrete bridges was in the construction of a 68 m-span bridge across the Rio de Peixe in Brazil in 1930. Twenty one years later, the first post-tensioned cast-in-situ concrete bridge using the balanced cantilever method was competed in Germany. Since then, the system has improved over the years and gained popularity for use in the construction of long span bridges throughout the world. A new world record was set with the construction of Stolma Bridge in Norway which has a main span of 301 m and opened in 1998.

CANTILEVERING METHODS

Free cantilevering is a method of construction where a structure is built outward from a fixed point to form a cantilever structure, without temporary support, using staged cast in-situ construction. When two opposing free cantilever structures are attached as a single structure and erected in the same step, it is known as 'balanced cantilever'.

In basic terms, cast-in-situ construction describes a process whereby segments are progressively cast on site in their final positions within the structure. By comparison, for precast construction, the segments are prefabricated at a casting plant – either on site or at a remote facility – then transported to the project site and erected as a completed unit in their final positions.

Precast balanced cantilever construction

CONSTRUCTION SEQUENCE

In cast-in-situ balanced cantilever construction, a starter segment is first constructed over a pier column. The starter segment is called a pier table. From this starting point, the bridge can be built from a single pier or multiple piers using form travelers moving toward mid-span. At mid-span, both adjacent cantilever tips are connected to make a continuous structure with a closure pour segment.

DESIGN CONSIDERATIONS

In a classic construction project, typical segments range from 3 m to 5 m in length and vary in height. The superstructure is normally designed as a haunch girder with a length-to-height ratio of around 17 over the pier and approximately 50 at mid-span.
A simple design, such as a box section, offers a rapid and economical formwork operation.

POST-TENSIONING

Long span balanced cantilever bridges require post-tensioning. The stresses are smallest at the cantilever tip and increase to a maximum adjacent to the pier. A series of post-tensioning tendons – known as cantilever tendons – are located in the top deck as close as possible to the web to resist the tension. After closure, a redistribution of stresses takes place reducing the values applied during construction. To balance these tension stresses which reach their maximum at mid-span, tendons are located in the bottom slab.

FORM TRAVELERS

BBR form travelers are self-launching structural systems that are supported off the leading cantilever tip and are used to support the segment formwork and weight of the newly cast segment. The form traveler remains in place until the new segment has gained sufficient strength to be post-tensioned to the previous cantilever segment – where it will remain, in its final structural position.

WORKING CYCLE

A working cycle begins after placing concrete for a new segment. One working cycle can be accomplished in one week after the learning curve has passed. However, 4-5 day cycles are also achievable. Several benefits have contributed to the success of the balanced cantilever method. One of the most important advantages is the repetitive working cycle that is used to construct each segment, which leads to efficient and rapid construction of the superstructure.
This proven method is recognized as a safe technique. The balanced cantilever method should only be applied by experienced contractors such as BBR Network Members who – because they are familiar with all the challenges which might occur during construction – are in a position to maximize the benefits of the technique for the project. Professional specialized BBR teams in various regions in combination with balanced cantilever equipment, including form travelers, ensure the highest quality in its execution. ●

Cantilevering ...

Maslenica Bridge, Croatia

Over the last 30 years or so, the BBR Network has successfully executed dozens of balanced cantilever projects – cast-in-situ and precast – all over the world. BBR Network Members have a proven record through all construction stages from preliminary design to execution and provide professional support to consultants, designers, owners and contractors.

The projects featured here are just a small selection from our portfolio of cantilever bridges. Other schemes, featured in earlier editions of *CONNAECT,* include the 1,040 m Batang Baram Bridge in Malaysia, Hundvakoy Bridge with a main span of 233 m, Norway, Milowka Flyover, Poland, Lawrence Hargrave Drive in NSW, Australia and more.

FJORD COUNTRY

Set in some of the world's most dramatically beautiful landscapes, part of the little municipality of Herøy in western Norway, consists of a small group of eight islands. The 543 m long **Herøy Bridge,** which opened in 1976, is a vital link to the mainland. It was constructed by BBR Network Member KB Spennteknikk AS, using balanced cantilever technology.

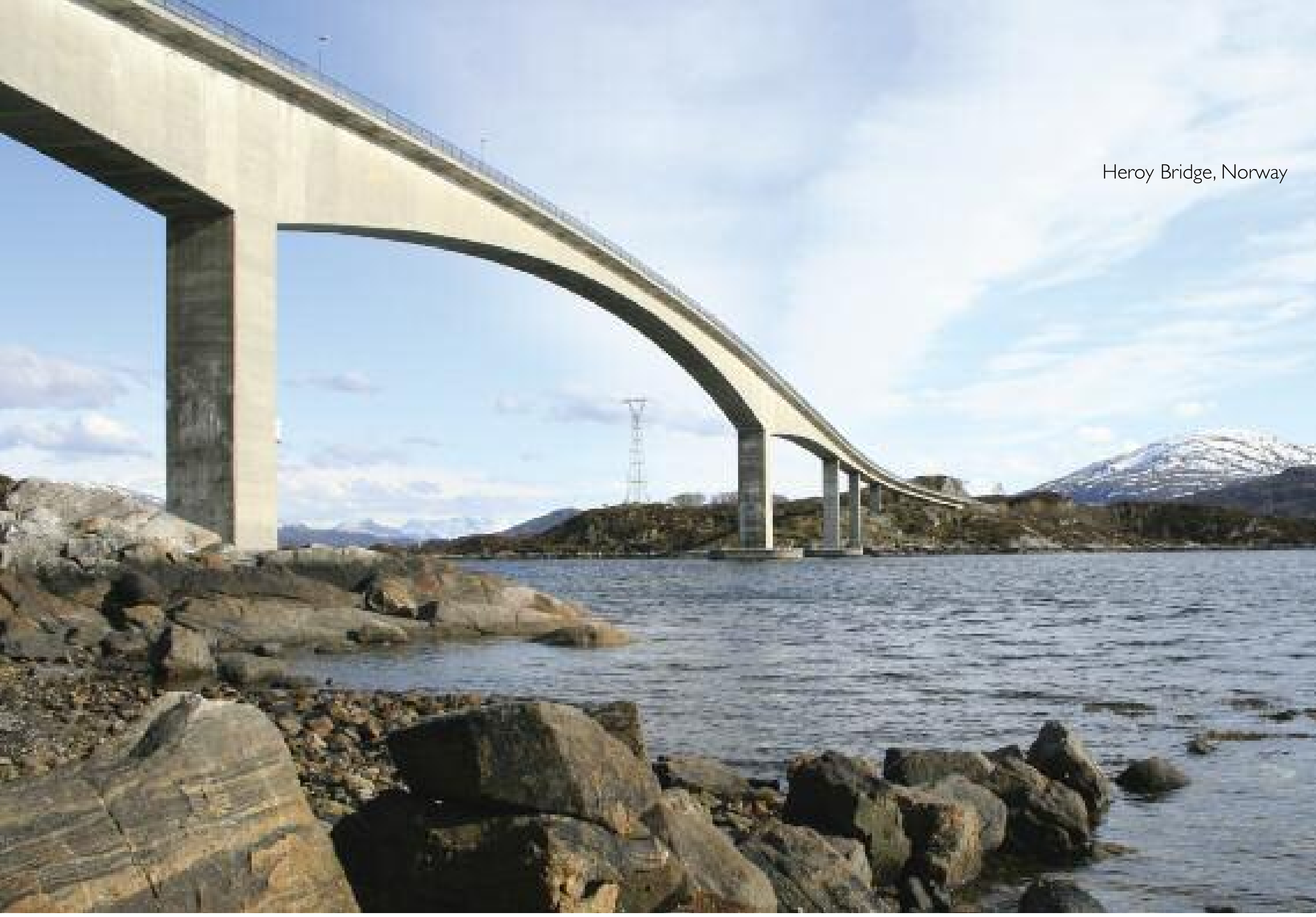
FIRST IN CROATIA

Moving southwards towards the Mediterranean, a striking 340 m long arch bridge carries Croatia's A1 north-south motorway across the Maslenica Strait of the Adriatic Sea. **Maslenica Bridge** is significant as it is the first motorway reinforced concrete arch bridge comprising a substantial span to be executed in Croatia.

The bridge was designed by Jure Radic and his team at the University of Zagreb's Faculty of Civil Engineering and built by Konstruktor-Engineering d.d. between 1993 and 1996. A hybrid form of the free cantilevering method was employed – which used temporary 7 mm BBRV stay- and back-stay cables, as well as two provisional steel pylons to stabilize the arch during construction.

The reinforced-concrete arch was executed in 5 m long segments – after the erection of the 23 elements on both sides, a final gap of 2 m remained open. The form traveler on one side was dismantled to let the other pass by. To bring both arch ends to the same level, steel beams on the upper part of the arch were installed, connected and one side post-tensioned with vertical bars prior to the closing pour. Prefabricated girders required for the structure were executed and prestressed in a purpose-built plant on the site. The team from BBR provided an alternative design for arch erection, including form travelers. Due to the versatility of the form travelers, no additional formwork or scaffolding was required, thus reducing overall costs.

Bloukrans Bridge, South Africa



Heroy Bridge, Norway

...across the world

LARGEST IN AFRICA

Situated along South Africa's Garden Route at the Tsitsikamma Forest Village Market, just 40 km east of Plettenberg Bay along the N2 Highway is **Bloukrans Bridge** – the highest and largest bridge in Africa, the third highest and the largest single span concrete arch bridge in the world.

The 451 m long bridge, completed in 1984, stands at height of 216 m above the Bloukrans River gorge and has a 272 m central span. The central span was constructed using the stayed cantilever method whereby a tower was erected on either side of the gorge and cables temporarily radiate out from it to support individual sections of the arch until the two halves can be joined in the middle. BBR form traveler technology was used to support the work of main contractor Murray & Roberts.

Today, the bridge's primary use is for road traffic, as it carries national route N2, but it is also the site of the world's third highest commercially operated bungee jump, which has turned the bridge into a major tourist attraction for South African visitors.

BRIDGE TWINNING IN CANADA

In 1985, with the help of BBR form traveling technology, a twin bridge for the 1958-built **Burlington Bay Skyway Bridge** in Ontario, Canada was opened to road traffic. Today, both bridges are known as the Burlington Bay James N. Allan Skyway and form two carriageways of the Queen Elizabeth Way (QEW) highway linking Fort Erie with Toronto.

By the 1980s, the older bridge, a steel structure, could no longer accommodate the heavy traffic volumes, thus the second bridge was built. The bridges cross the narrow channel of water which separates Burlington Bay from Lake Ontario. The original bridge is 36 m high and 2,560 m long from abutment-to-abutment while the newer bridge is 400 m shorter.

Burlington Bay Skyway Bridge, Canada

PILZNO, SANDOMIERZ AND GRUDZIADZ BRIDGES, POLAND


Grudziadz Bridge

Crazy for cantilevering


Grudziadz Bridge

1

While the cantilever method of bridge construction has been used around the world for many years, it was not until the 1990s that it found favor in Poland. With the launch of BBR Technology onto the Polish market, modern cantilever bridges started to emerge and now, the benefits having been realized, there are three currently under construction, reports Jacek Sowa, **BBR Polska's** specialist in that field.

BBR Polska has taken part in the construction and often also the design of almost all the cantilever bridges built in Poland so far – having four sets of form travelers on our fleet is also a distinct advantage. Intensive expansion of road infrastructure, in preparation for hosting the Euro 2012 football finals which will be held in Poland, has resulted in another three orders for the operation of form travelers on projects at Grudziadz, Pilzno and Sandomierz.

1 ONE BRIDGE, THREE CONSTRUCTION SITES

The newest of the cantilever projects – the MA-91 motorway bridge over the Vistula river in **Grudziadz,** forms part of the A-1 Gdansk – Katowice motorway which runs from the northern to southern border of Poland. The width of the river, over 1 km between flood banks, and proximity of a protected green area – resulted in the design of the longest bridges (two identical carriageways) in Poland, with a total length of 1,953.6 m.

The MA-91 bridge consists of three parts. On the northern side, a 988.8 m long, 43 section incrementally launched overpass is being built. Over the river, a three-span post-tensioned cantilever superstructure has been designed with total length of a 400 m (110 + 180 + 110 m). On the southern side, a 25 section, 556.8 m long incrementally launched overpass is under construction – this is set in a horizontal curve with a 5,000 m radius.

We have been involved in this project right from the start – we participated in the design of the cantilever section and have supplied and serviced form travelers, CONA CMI internal (15-150, 19-150) and CONA CME external (19-150) stressing technology using a total of 2,275 t of steel and finally, the supply of modular expansion joints – the largest of which has a 900 mm gap.

Both overpasses are designed with span lengths of 48 m. Each typical section is 24 m long and stressed alternately with eight and ten 15-150 internal tendons. After finishing the launching, we will begin installing the 19-150 external post-tensioning tendons – in lengths of up to 200 m. The total width of the superstructure is 17.35 m, the box girder height is 3 m and web spacing is 8.5 m. The scope of work demands the erection of all four overpasses at the same time. Four independent, roofed production plants were built on the site – which, despite hard-frosts, performed their work successfully. During a standard weekly cycle, 96 m of superstructure is concreted.

Between the overpasses, the largest cantilever bridge has started to grow. Geological conditions forced the designer to make the end spans disproportionately longer than the main span – thus, the last 16 m will be erected on scaffolding. Using the cantilever method, 156 sections will be erected – these will be from 3.5 to 5 m long and weigh up to 225 t.

The superstructure has vertical webs spaced at 8.5 m and the height ranges from 10.3 m on top of the piers to 4 m in mid-span. We are using a classic internal post-tensioning system – 80 19-150 type tendons in the deck slab to counter negative moments and also 19-150 type tendons for the final stage in the bottom slab.

The starting elements, each as big as a three storey building, are supported by the pier and a steel temporary support – a second support located 22.6 m from the axis of the pier will be activated after finishing seven pairs of sections. Two main supports were erected in the river and this necessitated the construction of two navigable lanes to allow the passage of barge traffic. For efficient speed of work two 75 m span, 12 t capacity truss cranes were brought in from abroad. At the outset, the general contractor – SKANSKA NDI – planned to build the two cantilever bridges one at a time, but many delays forced them to order an additional four form travelers. →

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Sandomierz Bridge

On the MA-91 construction site, work is now proceeding on eight workfronts simultaneously – four production plants for overpasses and four cantilever spans. Within each workfront, our team is making contributions which are essential for the realization of the MA-91 bridge.

2 OUR TYPICAL JOB

Our next project was a bridge over the River Vistula in **Sandomierz** which was to form a new lane for the existing National Road 77 running on a bridge alongside.
A new cantilever structure with the same pier spacing was designed next to the existing truss bridge.
The spans of the new bridge are 84.8 + 3x 95.4 + 84.8 m and the height of the box girder is 5.6 m at the top of the piers and 3 m in mid-span. There are 72 cantilever sections in total, with lengths ranging from 2.69 m to 4.69 m.
The need to preserve the old pier spacing (optimal for steel structure) forced part of the end span (34.59 m) design to be constructed on scaffolding. Also four form travelers are being used here for erection – after completion of the first two cantilevers, these were dismantled and transported to the opposite shore for erection of the last spans.
This was the first time that the main contractor here – Mota Engil Polska SA – had carried out this type of construction in Poland. With good cooperation all round, combined with our huge experience and efficient speed of work, we maintained the standard one-week cycle. In addition, BBR Polska supplied and installed all post-tensioning which used a total of 170 t of 19-150 and 22-150 BBR VT CONA CMI tendons, pot bearings and three- and four-module expansion joints.


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2

3 SMALL BRIDGE, BIG CHALLENGE

The first structures to be erected were the bridges over the Wisloka river in **Pilzno,** in the south of Poland. It had been decided to demolish the existing four-span steel bridge and build two completely new three-span cantilever bridges in the same place.
The superstructure (41.5 + 84 + 41.5 m) is of a typical design with 19-150 CONA CMI internal tendons – requiring a total of 156 t of prestressing steel. The height of the box girder is 4.60 m at the top of the piers and 1.9 m in mid-span .
The bridges were erected using our four pairs of form travelers. By cantilevering standards, these bridges are very small – but that did not mean it was a simple or easy job. The very small dimensions of the box girder – with only 1.40 m of free space in mid-span and closing gap of only 1.60 m – caused problems with stressing and disassembly of


3

form travelers. The small dimensions of the end sections and closing gap forced partial disassembly of the front working platforms of the form travelers before moving onto the last sections. Also stressing in such a small space was no easy task. Requirements surrounding the sequence and schedule of work – erection of a new bridge, traffic diversion onto the new structure, demolition of the old bridge, erection of the second bridge, widening of the river – allowed the BBR team to prove their skills in the fast assembly and disassembly of form travelers.The mountainous course of the river and its shallow depth made it impossible to work from the water. Therefore, during disassembly of the form travelers, stationary truss cranes were used to their maximum. Also, we used a 70 t crane erected at the riverside – it took down elements from over the river and set them on the ground. Our efficient, organized and well-executed work made a huge impression on the general contractor – Skanska SA, who could speed up their work by about one week.

UNEXPECTED TURBULENT WEATHER

In 2010, the weather in Poland was not very kind to civil engineers – there was a hard frost at the beginning of the year and record-breaking floods in the spring caused major problems on all three of our cantilever bridge projects. In Pilzno, the mountain river rose few meters one Sunday night and immediately swamped the construction site. Fortunately, the flood caused no major damage – just one week later, normal construction activities were resumed.
A similar situation occurred in Sandomierz – the river flooded the whole construction site – and half of the city. This halted work for a few weeks, but the form travelers on the cantilevers – one only half-assembled – were not in danger. A week later, the same mass of water reached Grudziadz. At the height of the MA-91 bridge works, the river was 1 km wide – the surrounding area and roads were totally flooded. What is more, just two weeks later, the same thing happened again – access to the almost finished starting elements was completely cut off. When the flood waters subsided, everybody worked doubly hard and the late 2011 completion date for the bridge remains intact. With such dramatically inclement weather, the advantages of balanced cantilever methodology were well-proven! ●

TEAMS & TECHNOLOGIES

1 2 3
BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

1 **GRUDZIADZ**
OWNER Gdansk Transport Company
MAIN CONTRACTOR SKANSKA NDI
DESIGNER Wanecki Sp. z o.o. Firma Projektowa (in collaboration with BBR Polska & CEPAS, Switzerland)
TECHNOLOGY BBR VT CONA CMI internal
BBR VT CONA CME external
Balanced cantilever

2 **SANDOMIERZ**
OWNER General Directorate for National Roads and Motorways, division in Rzeszow
MAIN CONTRACTOR MOTA ENGIL
DESIGNER Promost Consulting (in collaboration with BBR Polska & CEPAS, Switzerland)
TECHNOLOGY BBR VT CONA CMI internal
Balanced cantilever

3 **PILZNO**
OWNER General Directorate for National Roads and Motorways, division in Rzeszow
MAIN CONTRACTOR SKANSKA SA
DESIGNER Mostoprojekt
TECHNOLOGY BBR VT CONA CMI internal
Balanced cantilever

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