CONNECT

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Third Edition 2009

Peak of perfection

BBR VT CEO on Swiss quality and a return to true values

Bridges linking Europe

Free cantilever package delivers timely solution in Poland

Staying power in Valencia

Calatrava's masterpiece – executed with the latest BBR stay cable technology

The real thing

State-of-the-art distribution facilities in Australia for world's best known brand

New technology for Russia

Innovative and sustainable approach to cement silos

THE MAGAZINE OF THE GLOBAL BBR NETWORK OF EXPERTS

BBR A Global Network of Experts

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The BBR Network is recognized as the leading group of specialized engineering contractors in the field of post-tensioning, stay cable and related construction engineering. The innovation and technical excellence, brought together in 1944 by its three Swiss founders – Antonio Brandestini, Max Birkenmaier and Mirko Robin Ros – continues, more than 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 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); KB Spennteknikk AS (Norway), BBR Polska Sp. z o.o. (Poland) and VORSPANN-TECHNIK GmbH & Co. KG (Austria / Germany), all members of the KB Group (Norway); BBR Pretensados y Técnicas Especiales, S.L. (Spain), a member of the FCC Group (Spain).

With the world financial crisis dominating the news in recent months, you might expect business confidence to be at a low ebb everywhere – but within the BBR Network, we are ready! We believe that any crisis also presents opportunities – on this occasion, there are many accelerated infrastructure projects coming up in various countries to which our technology and skills are ideally suited.

The BBR Network approaches each new challenge with continued professionalism and yet more innovative solutions based on the finest Swiss technology – as you will discover when you turn the pages of this edition of CONNAECT.

Clients all around the world are now experiencing and appreciating the benefits of our very latest and most stringently tested technology – and when this comes together with the skill of BBR Network members, BBR becomes a compelling brand. Our brand is further strengthened by the sharing of knowledge and resources between BBR Network members – the joint ventures and collaborations during the past 12 months have delivered some outstanding results. Through our people and technology, we can help to deliver certainty of outcome – not only for main contractors and their clients, but also for the communities for whom the structures are created.

With our dedicated teams working together around the world – and our always up to date and fully certified technology – the BBR Network is in a very strong and competitive position as the world begins to feel the effects of this recession.

Bruno Valsangiacomo
Chairman
BBR VT International Ltd

Marcel Poser
CEO
BBR VT International Ltd

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PUBLISHER BBR VT International Ltd
NUMBER OF COPIES 11,000

SOURCES AND REFERENCES

Bridges section
Delivering certainty: en.wikipedia.org & www.kuala-lumpur.ws
Buildings section
The real thing: www.thecoca-colacompany.com
Tanks & Silos section
Superior storage solutions: www.lafarge.com, www.industryeurope.net & www.polski-cukier.pl
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Landmark Structures section
Highest tension: www.skycityauckland.co.nz
Scaling new heights: www.sydneytoweroztrek.com.au

Part of a major pan-European highway, the new River Bug Bridge in northern eastern Poland was a complex free cantilever construction requiring two sets of form travelers.

Calatrava's elegant new masterpiece in Spain provides not only a focal point for Valencia, but also reassurance that the very latest technology has been applied – the BBR HiAm CONA Stay Cable system.

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Buildings

The Grümpental Bridge in Germany features the longest concrete arch for a railway bridge in Europe – realized with heavy lifting know-how from the BBR team.

Structural Systems – the BBR Network member in Australia – has been playing a major role in the realization of two state-of-the-art distribution centers for Coca Cola Amatil (CCA).

The Shurovo Cement Works in Russia has three new silos. They were constructed using European approved BBR VT CONA CMI technology.

Tanks & Silos

Special Applications

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Landmark Structures

Marcel Poser, BBR VT International's CEO shares his thoughts about the excellent reputation of Swiss technology, his views on the current world financial crisis and the way forward not only for BBR, but also for the global community as a whole.

Peak of

Q: WHAT IS IT WITH SWISS PRECISION?
MP: Probably people in Switzerland are born with this – OK, that sounds boastful, but it's true nevertheless. Down the years, the Swiss have always produced innovative, precise and reliable technology, it's something we do well here – we always seek to achieve the peak of perfection.

Q: WHY DO YOU THINK THAT IS?
MP: I guess Switzerland breeds and attracts perfectionists! The environment we live and work in is a key influence – it's a well-organized and tidy sort of place, so it naturally follows that we have very high quality standards for everything we produce. Today, around 20% of our working population comes from other countries and I think this international blend of expertise flourishes within a Swiss environment and strengthens our ability to compete in the international arena.

Q: HOW HAVE YOU CAPTURED THIS FOR BBR?
MP: To an extent, this has happened naturally. Like most companies in Switzerland, we've attracted a range of international talent onto our team and when you add the feedback and support of our global network, it becomes a powerful combination – international expertise and knowledge management, Swiss technology and world class products.
We are absolutely focused on delivering technology that really is leading edge and going beyond this, we've created a working culture based on good people around the globe and on strong knowledge management which thrives on the sharing of resources and knowledge to deliver the very best results for everyone.

Q: SO, ARE YOU SAYING THAT BBR IS UNIQUELY PLACED?
MP: Exactly – and we've gone still further. We now live in an age where knowledge is king – instant access to information is crucial to competing effectively. Recognizing this, we've just launched BBR E-Trace – a web-based knowledge management, procurement and quality assurance system which allows the BBR Network to procure all products electronically, perform and document all quality assurance procedures online, as well as giving the network direct access to our technical archive. →

"LIKE MOST COMPANIES IN SWITZERLAND, WE'VE ATTRACTED A RANGE OF INTERNATIONAL TALENT ONTO OUR TEAM AND WHEN YOU ADD THE FEEDBACK AND SUPPORT OF OUR GLOBAL NETWORK, IT BECOMES A POWERFUL COMBINATION – INTERNATIONAL EXPERTISE AND KNOWLEDGE MANAGEMENT, SWISS TECHNOLOGY AND WORLD CLASS PRODUCTS."

"DOWN THE YEARS, THE SWISS HAVE ALWAYS PRODUCED INNOVATIVE, PRECISE AND RELIABLE TECHNOLOGY, IT'S SOMETHING WE DO WELL HERE – WE ALWAYS SEEK TO ACHIEVE THE PEAK OF PERFECTION."

Perfection

Q: BUT WHAT ABOUT SHARING KNOWLEDGE WITHIN THE CONSTRUCTION INDUSTRY AS A WHOLE?

MP: Actually, I make a point of taking part in industry dialogues and fundamental technical committees – personally. You have to drive these things from the highest level and, despite the time this takes, it's an investment in future success. And it's only in this way that a company's technologies and services can be thoroughly understood, regulated and promoted.

Q: HOW WILL THE CURRENT FINANCIAL CRISIS AFFECT BBR?

MP: We have all been here before, but sure, there will be some effects. Our financial position at BBR VT International is very stable – while we are committed to constantly improving our technologies, products and our people, we do this in a measured way. The development work we have undertaken over recent years makes BBR a safe and sustainable choice for our customers – and we have put a lot of development effort into technologies well-suited to infrastructure projects which, in the current environment, are the ones earmarked to be accelerated in many countries. For a professional and innovative organisation like the BBR Network, although times might be tough, out of a crisis will come opportunities – we will be helping our members and we will be helping each other as a network to align our businesses to capture these.

Q: WHY DO YOU BELIEVE THERE ARE OPPORTUNITIES IN A CRISIS?

MP: The opportunities are three-fold – for the whole of our planet, our cultures and individuals within them. I hope that this is a chance to move away from the bad practice of the past and think longer term. The current financial crisis has its roots in unsustainable practice – things like lack of knowledge, short-term profiteering and unethical behavior generally. As the global economy recovers, the something-for-nothing culture will hopefully reduce and we will begin to look ahead – but while considering whole-of-life cycles this time.

Q: WILL THIS RECOVERY HAPPEN ANY TIME SOON?

MP: Certainly it'll take a couple or three years before values get to where they should really be, but the focus will be on true values – the message will be loud and clear that cheaper is not necessarily the best for our future. While you always need to optimize costs, it should never be by simple and blind cost-cutting. Although it sounds harsh, sometimes you first have to spend one dollar to make two. If you try to make one dollar without spending anything, at best you will end up where you were before and at worst there will be negative results – in the short-to-medium term, this will all backfire. There needs to be a finely tuned balance between spending where you have to spend and optimizing where you can optimize. This doesn't just apply to money, but to effort as well – if you put a lot in, you'll get a lot back. This is especially valid for times like these. And there are definitely areas where you can optimize, but this must be done carefully!

Q: DO YOU THINK THIS IS THE END OF GLOBALIZATION?

MP: No, no – it will continue but I believe that it will take on a more responsible and sustainable form. For example, there will be a stronger focus on true knowledge – business will rely on people who live and work in the markets in which they operate. This has been the BBR market model – by building a network of local organisations who run businesses in various regions of the world, you benefit from optimized costs where globalization or centralization makes sense, while customers have the huge advantage of local expertise and local market knowledge, combined with the backing of shared international know-how.

Q: WHY IS BBR AHEAD OF THE GAME?

MP: Well look, it's all in the development and the quality of our people around the world. Within the BBR Network we have always walked the walk first, before we have talked the talk – marketing is good, but if you scratch the surface you might discover that companies haven't actually done the work. You only have to look at the testing we've completed – and we actually did more than was required – to know that there is substance behind our claims ... and lots of engineering work! We also invest in the BBR Network. We encourage and facilitate the sharing of knowledge and resources between members.

Q: HOW HAS BBR REMAINED SUCCESSFUL FOR SUCH A LONG TIME?

MP: We've been around for a long time – and experience is very important – but you have to be careful that it does not make you blind to where things are going and how all sorts of conditions change over time. You need to look beyond the boundaries and align with the ever-changing needs of the market – become a 'listening organisation' which truly hears what the market wants. OK, so we've got over 60 years' experience with the BBR Network, but going the extra mile has become a habit for us – and it's something that we have been doing very well indeed! However, we must bear in mind that such things do not happen by accident, so it is particularly fitting that I should express my thanks now to the shareholders and board of directors of BBR VT International for their vision and confidence over the past five years, which has placed us in this enviable position.

Swiss quality **assurance**

Investment in the development and testing of new technologies for the construction industry have put the BBR Network in a market-leading position. The BBR VT International team has now broken their own world record while carrying out certification testing of high capacity tendons to the Guidelines for European Technical Approval (ETAG) 013 specifications. They achieved a record tendon capacity of over 20,000,000 N – more than seven times the weight of an Airbus A380 aircraft! ➔

Over recent months, the team has performed tests on a variety of sizes and configurations of BBR VT CONA CMX anchorages – ranging from 1 to 73 strands. So far, we have carried out 122 static, 78 fatigue and 33 load transfer tests – and we're still counting! In addition to the mandatory tests, we have successfully performed a large number of special installation, stressing, deviator / saddle and grouting tests. Today, we have the best technology available – backed by the European Technical Approval (ETA) and the associated Certificate of Conformity (CE) we have secured.

STATE-OF-THE-ART POST-TENSIONING

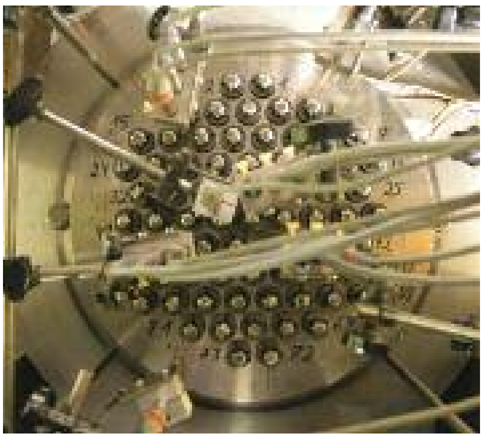
The BBR Network offers a complete range of post-tensioning (PT) systems which have been applied to a vast array of different structures – such as bridges, buildings, tanks, dams, power stations and just about any other structure you can think of.

In addition to the BBRV wire PT technology and BBR CONA strand systems that have been used successfully for many decades, we have created some completely new technology – the BBR VT CONA CMX family – which incorporates current market needs with all the advances and knowledge gained over the past 60 years by the BBR Network.

The BBR VT CONA CMX range consists of five systems which cover the entire spectrum of post-tensioning needs:

- ◆ BBR VT CONA CMI – internal post-tensioning system
- ◆ BBR VT CONA CMM – unbonded post-tensioning system
- ◆ BBR VT CONA CME – external post-tensioning system
- ◆ BBR VT CONA CMF – flat anchorage post-tensioning system
- ◆ BBR VT CONA CMB – band post-tensioning system

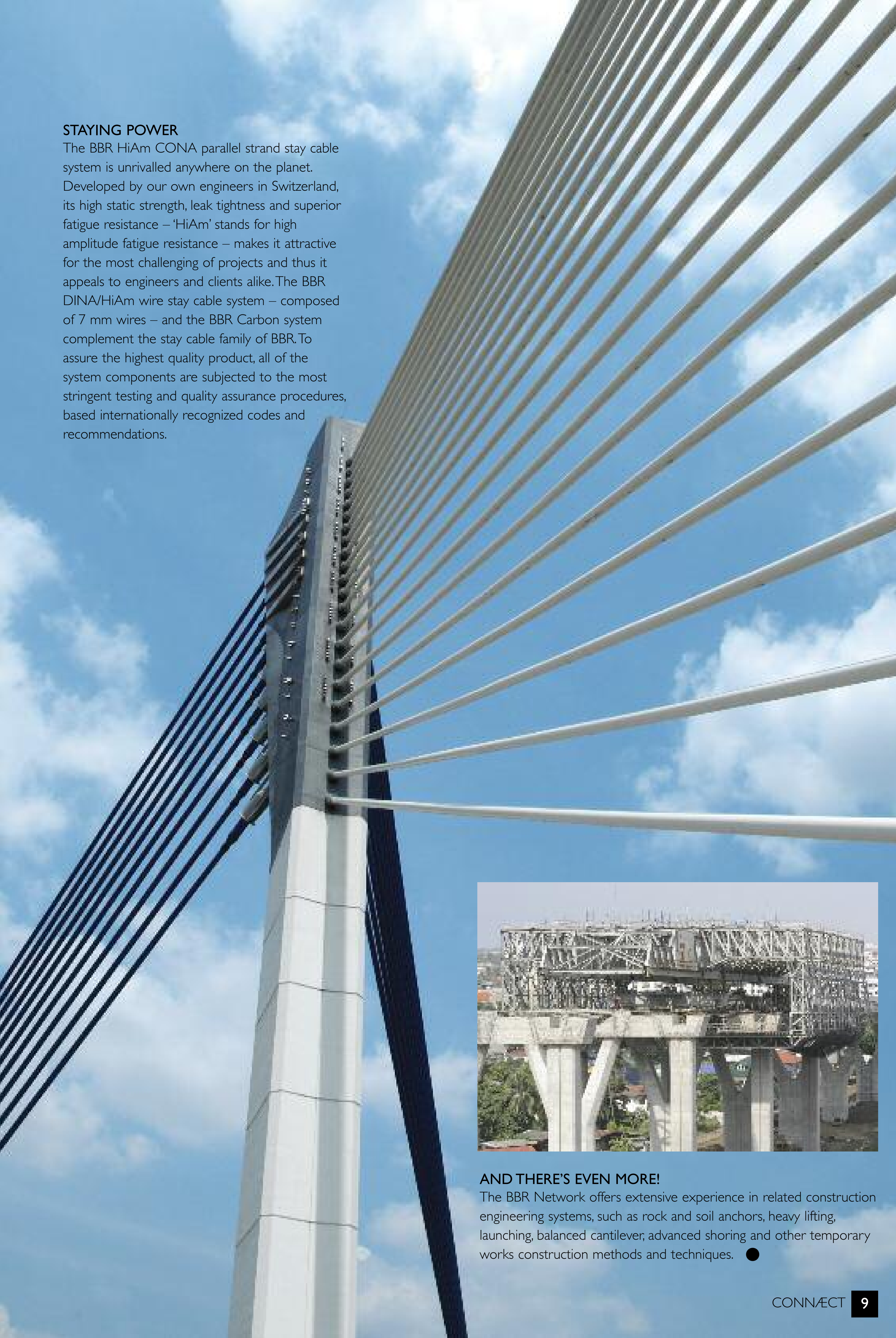
BBR products continue to promote faster construction programs through early strength concrete stressing which reduce the construction cycle time. BBR technologies remain the benchmark for compactness in the anchor zone. Furthermore, a wide product range and size offering promotes the use of only what is really needed.



BBR e-Trace

ASSURING QUALITY

BBR E-Trace is an integral part of the BBR VT CONA CMX quality assurance. The internet-based software links all members of the BBR Network – including BBR PT Specialist Companies, BBR component manufacturers and BBR headquarters. This comprehensive web platform fulfils the vision of e-commerce. It covers supply chain management, procurement and communication, as well as providing an engineering database and quality management system which includes traceability and document control.



STAYING POWER

The BBR HiAm CONA parallel strand stay cable system is unrivalled anywhere on the planet. Developed by our own engineers in Switzerland, its high static strength, leak tightness and superior fatigue resistance – 'HiAm' stands for high amplitude fatigue resistance – makes it attractive for the most challenging of projects and thus it appeals to engineers and clients alike. The BBR DINA/HiAm wire stay cable system – composed of 7 mm wires – and the BBR Carbon system complement the stay cable family of BBR. To assure the highest quality product, all of the system components are subjected to the most stringent testing and quality assurance procedures, based internationally recognized codes and recommendations.

AND THERE'S EVEN MORE!

The BBR Network offers extensive experience in related construction engineering systems, such as rock and soil anchors, heavy lifting, launching, balanced cantilever, advanced shoring and other temporary works construction methods and techniques. ●

GLOBAL BBR NETWORK CONFERENCE

International networking

Every year, the BBR Network meets at an annual conference – providing both a forum for the exchange of information and an opportunity to get to know other BBR Network members informally.

SYDNEY 2008

In 2008, the BBR Network got together in Sydney, Australia where, besides a number of BBR technology updates, the international BBR family participated in a charity golf tournament – and still had the energy to climb the Sydney Harbor Bridge! The conference reached its climax with the formal BBR dinner – during which the winner of the 2008 BBR Project of the Year award was announced.

PARIS IN SPRING 2009

In April 2009, our annual conference will take place in Paris – a perfect time to be in that great city which is sure to inspire some productive discussions and knowledge-sharing. BBR Network members will be presenting information about challenging applications and the team from BBR Headquarters will give updates on commercial and technological developments. Of course, several social events will complement the conference.

BBR Project of the Year 2008

ROSS RIVER DAM UPGRADING, AUSTRALIA

With many dams worldwide requiring upgrading to meet revised safety standards, work carried out on the Ross River Dam is an excellent example of a special post-tensioning application and the leading edge technology employed by the BBR Network. Australian BBR Network member Structural Systems executed the permanent anchoring and trunnion restraint tendon works. Using BBR CONA ground anchors, the team have helped to secure the dam for the local community.

Among the vast number of applicants, the Ross River Dam project convinced the jury most because the project so perfectly demonstrates the long-standing capability of the BBR Network in the use of specialist large capacity tendons for the upgrading of dams around the world.
As a result of their excellent work on this project, Structural Systems have recently been awarded the contract for upgrading the Catagunya Dam in Tasmania where the task will feature the installation of permanent anchors with the highest breaking load ever installed in Australia!

Bridges linking Europe

As part of the widening of an important pan-European highway route, a new bridge has been built over the River Bug in Poland. Piotr Stasyk of **BBR Polska,** the BBR Network member in Poland, explains how this free cantilever structure was realized. ➔

The S8 Express road in north-eastern Poland is part of pan-European transit passageway linking the Baltic countries and Finland with Poland and the rest of Europe. The growing volume of traffic has necessitated widening of the road to increase capacity.

The task, consisted of three parts – modernization of a two lane road, widening of the existing road and a most important part of the task – building the Wyszków bypass and, by the free cantilever method, constructing a bridge over the River Bug.

DESIGN CONCEPT

Two independent structures were designed as a continuous nine span beam with a total length of 600 m. Three main spans (80 m + 136 m + 80 m) were built using the free cantilever method and were cast in-situ, while the side spans were built using traditional formwork. The height of the box girder is 7.5 m at the top of the piers and 3.1 m in midspan. All tendons have been designed as internal, 19-150 type – and the steel used weighed in at a total of 518 t. The 38 tendons for

negative moments during the cantilevering phase are located in the deck slab and post-tensioning for the final stage was laid out to accommodate the bending moment.

ADDITIONAL FORM TRAVELERS

The original schedule called for completion of both structures using only one pair of form travelers. Such were the delays, caused by a harsh winter and flooding, that the only way to make up time was by adding a further pair of form travelers. Adopting this approach meant that one specialist team – consisting of an engineer and six technicians who had originally been designated to operate one pair of travelers – then had to work simultaneously on two pairs. In addition, two different types of traveler were used for concreting. In spite of this, we managed to maintain a one week cycle for concreting – mainly thanks to the experience of our specialist team which has much experience gained over a long history of free cantilever projects!

THROWING DOWN THE GAUNTLET

The co-ordination of simultaneous work on four travelers, located on both sides of the river, and erecting side spans was a real challenge. The requirement to maintain a weekly cycle, even in winter, forced the contractor to take additional measures with regard to the concrete – special tents and heating machines were used. And, despite freezing night-time temperatures, work continued around the clock. Concreting of the bridge superstructure was completed in spring 2008.

ANOTHER 'PACKAGE' DEAL

It is worthy of note, that the Wyszków contract is another example of a 'package deal' that BBR Polska has agreed with a contractor PRM "Mosty Łódz" S.A. – as described in the previous edition of CONNAECT. Our scope of work here also included the design of temporary supports, pre-camber deflection calculations, supply of stressing bars up to 50 mm diameter, supply and installation of 36 pot bearings and two 3-module expansion joints.

Our experience from Wyszków proves that we are able to operate on any cantilever bridge – with any type of form traveler – and complete the bridge on time. To date, all free cantilever bridges built in Poland since 1998 have been constructed with the expertise of the BBR team.

"TO DATE, ALL FREE CANTILEVER BRIDGES BUILT IN POLAND SINCE 1998 HAVE BEEN CONSTRUCTED WITH THE EXPERTISE OF THE BBR TEAM."

TEAM & TECHNOLOGY

OWNER GDDKiA, Warsaw

MAIN CONTRACTOR
PRM "Mosty Łódz" S.A.

DESIGNER Profil Sp. z o.o.

TECHNOLOGY BBR CONA internal
Balanced cantilever

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

PERTH BUNBURY HIGHWAY BRIDGES, CITY OF MANDURAH, AUSTRALIA

First use of BBR VT CONA CMI in Western Australia

Hudson Lun, of Australian BBR Network member **Structural Systems,** writes that the Southern Gateway Alliance recently began construction of a dual carriageway around the city of Mandurah to remove congestion and improve the traffic flow into this popular wine region in the south west of Western Australia. This link will form part of the New Perth Bunbury Highway.

The Southern Gateway Alliance is an alliance between Government, consultants GHD and Leighton Contractors. The scheme had four incrementally launched bridges in which we were involved. The design was changed to incorporate the new BBR VT CONA CMI multistrand system. The project consists of two bridges over the Serpentine River and two over the Murray River with individual bridges for each direction of traffic. Each of the Serpentine bridges consisted of seven segments giving them an overall length of approximately 110 m. Four sets of launching jacks were used for the incremental launching, as each bridge was constructed and launched in tandem. The Serpentine bridges had approximately 100 t of post-tensioning with 1206, 1906 and 3106 anchorages and couplers.
The Murray River bridges started shortly after the completion of the Serpentine River bridges. Each of these bridges consists of 18 segments with an overall length of approximately 280 m. The launching equipment from the Serpentine bridges was re-located and used for the launching of the Murray bridges. The Murray bridges had approximately 170 t of post-tensioning with 1206, 1906 and 2206 anchorages and couplers.

TEAM & TECHNOLOGY
OWNER Main Roads Western Australia
MAIN CONTRACTOR Southern Gateway Alliance
DESIGNER Wyche Consulting
TECHNOLOGY BBR VT CONA CMI internal Launching
BBR NETWORK MEMBER
Structural Systems Limited (Australia)

BRIDGES, BLAUWE STAD, NETHERLANDS

PT fulfills vision

Spanstaal, the BBR Network member for the Netherlands, Belgium and Luxembourg, reports on the post-tensioning of two bridges for the Blauwe Stad (Blue City) project – a newly developed recreation area in the north east of the Netherlands, between the cities of Scheemda and Winschoten.

This area, formerly reclaimed from the North Sea for agriculture, is now being developed for recreational use – and 800 ha will be used for water storage, as well as for water recreation. Adjacent to this, five different housing areas will be created with a total of 1,500 houses on plots of up to 7,500 m^2 each. Construction will be realized in different stages and is part of a wider ecological infrastructure plan in which, with the prospect of climate change, water storage will play an important role.

For such a visionary development, the use of the very latest technology in the field of post-tensioning – the CE-marked BBR VT CONA CMI system – was specified.

Two lightweight prestressed bridges are being built within this project to take a new road over the waterways. To meet the demands of heavy PT forces within a lower concrete density, we chose to use the BBR VT CONA CMI 2206 system.

Materials supply, installation and construction were carried out in accordance with the European Technical Approval Guidelines (ETAG) 013 and were well appreciated by the clients – who were delighted that their innovative project had an equally innovative PT system which fulfilled the latest demands.

For Spanstaal, this was our first use of the system in compliance with ETA guidelines – and we were also happy about the very positive experience gained! ●

TEAM & TECHNOLOGY

OWNER Projectorganisation Blauwestad
MAIN CONTRACTOR Ballast Nedam Infra North-East
DESIGNER D.H.V.
TECHNOLOGY BBR VT CONA CMI internal
BBR NETWORK MEMBER Spanstaal B.V. (Netherlands)

BRIDGES

BRIDGE BU2, BURGDORF, GERMANY

Reducing **traffic volumes**

BBR Network member, **Spankern,** was commissioned to carry out the post-tensioning work for the 48 m long BU2 bridge in Burgdorf, Germany. The superstructure consists of two concrete girders and a top slab – for each girder, eight BBR VT CONA CMI 1506-150 1770 tendons were used.

The B188 federal highway is an important East-West connection between Hannover and Wolfsburg in Germany. This heavily-trafficked road carries more than 20,000 vehicles per day – crossing the city of Burgdorf and creating a lot of noise and fumes for the local population.

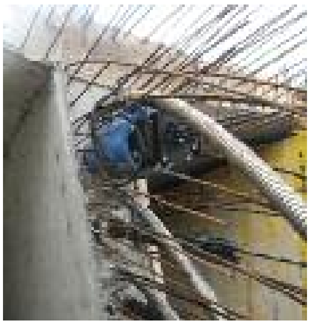
To alleviate the situation, a new 7.6 km bypass, along with various bridges, is under construction. The new overpass bridge BU2 is part of the bypass and traverses the existing B443 highway. ●

TEAM & TECHNOLOGY

OWNER Niedersächs. LB für Strassenbau und Verkehr
MAIN CONTRACTOR Mölders Baugesellschaft mbh
DESIGNER Mölders Baugesellschaft mbh
TECHNOLOGY BBR VT CONA CMI internal
BBR NETWORK MEMBER Spankern GmbH (Germany)

Economies with moveable couplers

Two new bridges are being built alongside existing ones on Austria's A9 Pyhrn Motorway. Rudolf Vierthaler of **VORSPANN-TECHNIK,** the Austrian BBR Network member, describes how his company used moveable couplers, to the requirements of European Technical Approval Guidelines, in the post-tensioning operation – a first in Austria.



Built in the early 1980s, the A9 links the A2 South Motorway with the A1 West Motorway. The motorway has already been upgraded to cope with increased traffic by widening and, for some bridges, additional decks have been constructed alongside existing ones.

LAYOUT OF THE STRUCTURES

The two additional bridges, B2.2 and B2.3, are located to the south of the Bosruck Tunnel. Bridge B2.2 is a continuous box-girder with a total length of 550.32 m, consisting of 13 spans with lengths ranging from 29.22 m up to 48.87 m, while bridge B2.3 has a total length of 312.86 m, consisting of seven spans of different lengths from 29.25 up to 48.95 m. The single-cell box-girder is 3.75 m high and the top slab is 14 m wide.

DECK ERECTION

The deck structure is erected on conventional formwork, span-by-span and has 20 sections in total. For each section, the first stage involves concreting the bottom slab and in the second stage, the two webs together with the top slab are concreted.

POST-TENSIONING

The post-tensioning for the structure is provided by BBR VT CONA CMI 1206-150 1770 bonded

tendons, as outlined in ETA-06/0147, with eight tendons per web.
In order to obtain consistency in the distribution of the compression forces within the structure, half of the tendons are stressed at the construction joints and elongated by fixed couplers, while the other tendons are elongated by moveable couplers, situated about two meters from the joint. The latter tendons are stressed and elongated by fixed couplers at the next construction joint.
The only alternative solution would be to produce tendons of a length equal to that of the two construction sections, without movable couplers. The advantage of moveable couplers is that the additional handling and intermediate storage of the long tendons – which protrude from the construction joint, ready for stressing at the end of the next section – can be avoided.

ECONOMIES WITH MOVEABLE COUPLERS

This was the first time that moveable couplers had been used under European Approval criteria in Austria. In this particular case, the costs for the moveable couplers are covered by the savings made in terms of labor to manipulate tendons for succeeding sections, as mentioned above.
As it was the first use of moveable couplers according to ETA requirements, a trial assembly was carried out prior to application on site. Since then, moveable couplers for more than ten sections have been successfully installed and stressed for the bridges in Ardning. ●

TEAM & TECHNOLOGY

OWNER ASFINAG
MAIN CONTRACTOR Massivbau GmbH
DESIGNER Schimetta Consult
TECHNOLOGY BBR VT CONA CMI internal
BBR VT CONA CMI moveable coupler
BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH & Co. KG (Austria)

Technical insight:
Fixed and moveable couplers

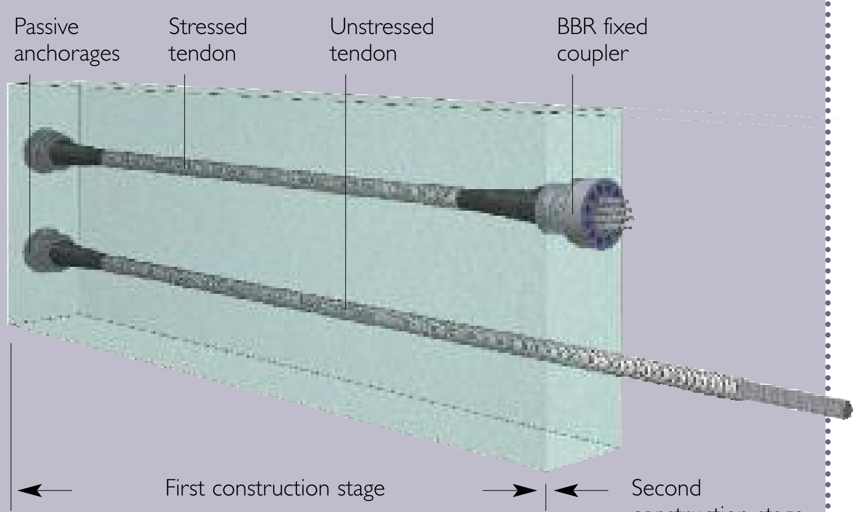
Basically, the function of a coupler is to connect two tendons – this applies to both fixed couplers and movable coupler types.

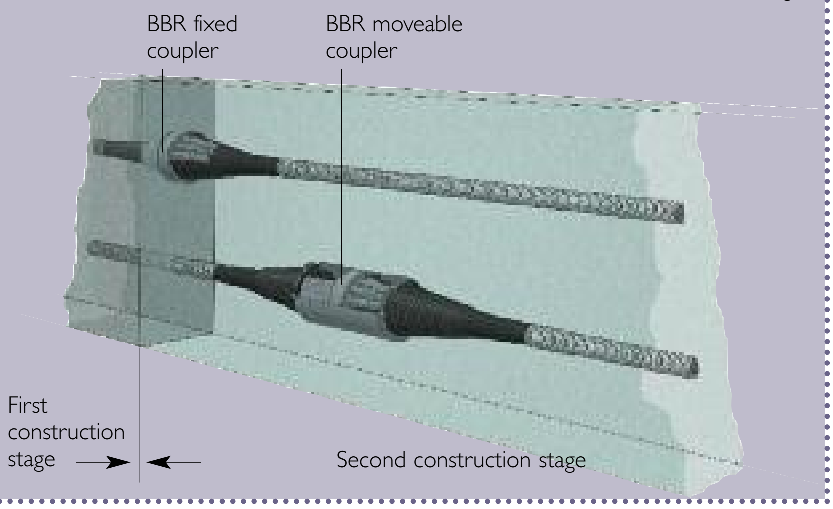
BBR FIXED COUPLERS

The tendon in the first construction stage is installed, stressed and anchored in the fixed coupler which is placed in the section joint between the first and second stage. Afterwards, the second stage tendon is put in place and coupling is achieved by pushing the strands into the already tensioned coupler anchor head.
It is good practice to design at least 30% of all tendons to be continuous in a section joint in order to obtain an even distribution of the prestressing force in the structure. This means that very long protruding tendons, from the first stage, have to be stored temporarily on the deck and this leads to time consuming handling.

BBR MOVEABLE COUPLERS

The moveable coupler serves to lengthen unstressed tendons and helps to overcome handling problems. Once the first construction stage is completed, the moveable coupler is mounted next to the joint and connected to the unstressed first stage tendon. At the same time, the strands of the second stage tendon are pushed into the coupler. Finally, after concreting the second stage, the complete tendon is stressed over both stages. The axial movement during stressing is ensured by a cylindrical sheathing box appropriate for the expected elongation at the location of the coupler.





Cross-border launch

ALBURY-WODONGA BRIDGE, AUSTRALIA

The Albury-Wodonga Murray River Bridge crosses the Murray River at the border between Victoria and New South Wales in Australia. Andrew Kiker from **Structural Systems,** the BBR Network member in Australia, reports on the construction of the twin bridges which were incrementally launched across the river.

The project was initiated to increase traffic flow through the border and reduce traffic congestion in the urban surrounds of Albury and Wodonga.

OVERVIEW

The Albury-Wadonga Murray River Bridge is a twin bridge with a main span of 50 m over 11 spans. The total length of the north bridge is 197 m and the south bridge is 210 m.
It is a concrete in-situ bridge, forming part of the Hume Freeway, which consists of box girders that were incrementally launched from the south side of the river in Victoria, towards the northern side in New South Wales. The project was funded by both the RTA and Victoria Roads and cost approximately A$ 15 million.

CONSTRUCTION

AbiGroup Contractors Pty Ltd were the main contractor and we were subcontracted to Fitzgerald Constructions Pty Ltd to perform post-tensioning design and installation and fixing of passive reinforcement. The bridge was incrementally launched, with post-tensioning being adopted to assist in the launching of each segment and provide long term durability with its longitudinal continuity and trensverse tendons.

Each segment consisted of:

- 4 x 31 strands in bottom flange for the launching tendons
- 2 x 31 strands in each wall for the continuity tendons (4 in total)
- 12 x 5 strands for the longitudinal tendons
- 11 x 5 strands for the transverse tendons

All tendons were 15.2 mm diameter, the multi-strand system was the BBR CONA internal 3106. Coupling in the launching tendons was the 3106, Type K and the slab system was our own 506 post-tensioning system.

PT METHODOLOGY

The launching tendons and longitudinal tendons were coupled at the end of each segment. To

optimize construction cycles for each segment, it was decided to prefabricate the launching tendons and roll them over a purpose-built handrail that could accommodate the temporary storage of such tendons. The transverse tendons were prefabricated on the ground and stored in a 15 m crate which was lifted by a crane and placed on the deck for easy installation of each tendon.

The launching tendons were prefabricated and placed over handrails. Once the previous segment had been launched, the tendons were already in place for the next segment. The continuity tendons were installed at one time, with 31 strands traveling the length of the bridge and then hooked up to the main group of strands which were laid in full along the ground. An articulated all terrain crane then pulled the dummy strand, with the main tendon, back through the bridge.

TIMELY COMPLETION

A high level of cohesion and understanding between such elements of post-tensioning and reinforcement meant Structural Systems was the best subcontractor for the job. As a result, one segment per week was cast – and essentially the main bridge structure was completed within 12 months. This method of construction ensured the project was completed on time for the official opening. It was a very public affair with thousands of onlookers witnessing the historic occasion.

AbiGroup were delighted by the professionalism and efficiency of its subcontractors and it proves once again that post-tensioning is a most viable option in bridge construction.

TEAM & TECHNOLOGY

OWNER Victoria Roads & RTA

MAIN CONTRACTOR AbiGroup Contractors Pty Ltd

DESIGNER Hyder Consulting Ltd (UK)

TECHNOLOGY BBR CONA internal Launching

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

ZALLAQ BRIDGE, KINGDOM OF BAHRAIN

Notable and commended

BBR Network member, **NASA Structural Systems,** successfully provided post-tensioning shop drawing, supply, installation, stressing and grouting services on the Zallaq Bridge project in the Kingdom of Bahrain. Warwick Ironmonger, General Manager, describes the project and his company's work.

This US$ 16 million project comprises the construction of a seven span bridge across Zallaq Highway together with the associated roadways. The project will extend the dual three-lane Sheikh Bin Salman Highway southwards, from its current termination point north of Zallaq Highway, over Zallaq Highway and into the grounds of Bahrain University.

Once the bridge is completed, the existing crossroads will be a thing of the past, and vehicles will be easily able to safely access Zallaq, the Bahrain International Circuit, the University of Bahrain and various towns and villages in the southern part of the Kingdom through the Sheikh Khalifa bin Salman Highway – and traveling time to these places will be reduced by about 20 minutes.

Each of the two bridge superstructures consists of a 2.65 m deep post-tensioned, in-situ reinforced concrete box beam over intermediate pier supports, to create an overall bridge length of 240 m. This length is decided by seven spans including two 25 m end-spans, four intermediate 35 m spans – and a fifth intermediate maximum span of 50 m, bridging Zallaq Highway.

This project is notable for the BBR Network in that it was the first application in the Middle East of the ETAG-013 approved BBR VT CONA CMX pre-stressing range. The 3106 BBR VT CONA CMI multi-strand system and the 3106 BBR VT CONA CMI, Type FK coupler system were effectively used to post-tension the bridge super-structure.

Prior to post-tensioning works commencing on the bridge, we undertook a full-scale grout trial to ensure nothing was left to chance in construction of the superstructure – and the professionalism extended by the Structural Systems team throughout this trial was commended by Hyder, the bridge designer.

The Ministry of Public Works has acknowledged that the bridge was an important component in the overall road network development plan and has expressed satisfaction with the speed and efficiency of the companies involved in the building of the bridge.

The bridge is expected to boost movement between Bahrain, Saudi-Arabia and Qatar, once the Friendship Causeway is built.

TEAM & TECHNOLOGY

OWNER Ministry of Public Works and Housing, Kingdom of Bahrain

MAIN CONTRACTOR
Hafeera / IJM Construction J.V (Bahrain)

DESIGNER Hyder Consulting Ltd (UK)

TECHNOLOGY
BBR VT CONA CMI internal

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

RAILWAY OVERBRIDGE, HAMILTON, NEW ZEALAND

Improving safety & traffic flow

A major highway running through New Zealand's largest inland city is being transformed from a busy urban road into a two kilometer bypass. A complex post-tensioning operation has been executed for a new railway overbridge, Keith Snow and Terry Palmer from **BBR Contech** – the BBR Network member in New Zealand – report on the project.

The New Zealand Transport Agency is constructing the new State Highway 1 Avalon Drive Bypass in Hamilton to reduce congestion, improve safety, and separate inter-regional state highway traffic away from internal city traffic. The new free-flowing high capacity route will reduce travel times, improve trip reliability and at the same time improve the surrounding residential and retail environment.

NEW RAIL OVERBRIDGE

The bypass includes a new railway overbridge, constructed over a lowered road and replacing a former railway level crossing. The bridge carries freight and passenger services on the North Island Main Trunk Line, with this particular section carrying more freight than any other in New Zealand. In a two month project, BBR Contech worked with main contractor Brian Perry Civil and designer ONTRACK to post-tension the bridge's cast insitu concrete deck.

MORE COMPLEX THAN MOST

The post-tensioning process was considerably more complex than for most similar bridges – mainly owing to the extensive use of reinforced steel in the bridge deck, which was 1.5 m thick, 19 m wide and about 26 m long. The work required post-tensioning tendons to be carefully interwoven with the heavy layers of conventional reinforcing. In total, 61 BBR CONA internal 1905 tendons, were installed in the bridge decking – comprising a total of 31 t of prestressing strand.

Fortunately the project had minimal effect on train scheduling, with two temporary tracks – one electrified – built to cope with the load. Once the bridge was complete, track, signaling and electrification equipment was relocated, enabling a simplified track layout and fewer, more streamlined connections. →

BENEFITS ALL ROUND

The railway overbridge is delivering a number of benefits to owner ONTRACK and road users alike. It has reduced track maintenance requirements and improved safety, and it means motorists no longer have to stop for trains at the level crossing. In addition, underpasses enable children to walk to school safely – away from a busy road and railway line.

TEAM & TECHNOLOGY

OWNER ONTRACK

MAIN CONTRACTOR Brian Perry Civil

DESIGNER ONTRACK

TECHNOLOGY BBR CONA internal

BBR NETWORK MEMBER
BBR Contech (New Zealand)

Bridge over **live tracks**

LIPA-ŠTORE BRIDGE, CROATIA

BBR Adria, the BBR Network member in Croatia, has been contracted to provide the post-tensioning for a bridge over the main Zidani Most to Maribor railway line.
The Lipa-Store bridge consists of a single prestressed concrete box girder across seven spans. The first six spans are being built using the incremental launching method, as there is live traffic on the railway track beneath. The last span will be cast in-situ and make the connection with the other side. For the prestressing, we are using BBR VT CONA CMI tendons in plastic ducts. The overall length between the abutments is 187.50 m and the bridge is on a 1.5% gradient.

TEAM & TECHNOLOGY

OWNER Javna agencija za železniški promet Republike Slovenije (Public agency for railway transport of Republic of Slovenia)

MAIN CONTRACTOR CM Celje, d.d.

DESIGNER V. Acanski, B.Sc. Civ. Eng.

TECHNOLOGY BBR VT CONA CMI internal

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

E18 MOTORWAY BRIDGES, LANGÅKER – BOMMESTAD, NORWAY

Speedy infrastructure partnership

Working hand-in-hand with main contractor Skanska to deliver an ambitious Public Private Partnership (PPP) motorway project valued at approaching € 80 million for Statens vegvesen, the Norwegian highways department, Spennteknikk – the BBR Network member in Norway – is very busy right now!

On average, every day as many as 20,000 cars pass through Langåker and around 25,000 through Bommestad. The frequent traffic jams were causing heavy congestion, accidents and having a serious impact on the environment. The new motorway will mean a whole new life for local communities and road users alike.

The project will see the construction of 8 km of four-lane motorway running from Langåker to Bommestad in south east Norway. We are supplying the post-tensioning for no less than 13 bridges on the new route. It is anticipated that we will use around 300 t of pre-stressing steel – and the BBR CONA internal 1506, 1906 and 3106 systems have been chosen.

The PPP approach is a way to speed up the realization of public sector projects which would otherwise wait many years to secure government funding. One further advantage for this project, driven by one main contractor, is that it will be completed two months ahead of the original schedule – in June this year. ●

TEAM & TECHNOLOGY
OWNER Statens vegvesen
MAIN CONTRACTOR Skanska
DESIGNER Norconsult/Interconsult
TECHNOLOGY BBR CONA internal
BBR NETWORK MEMBER
KB Spennteknikk AS (Norway)

Photographs courtesy of Byggeindustrien magazine.

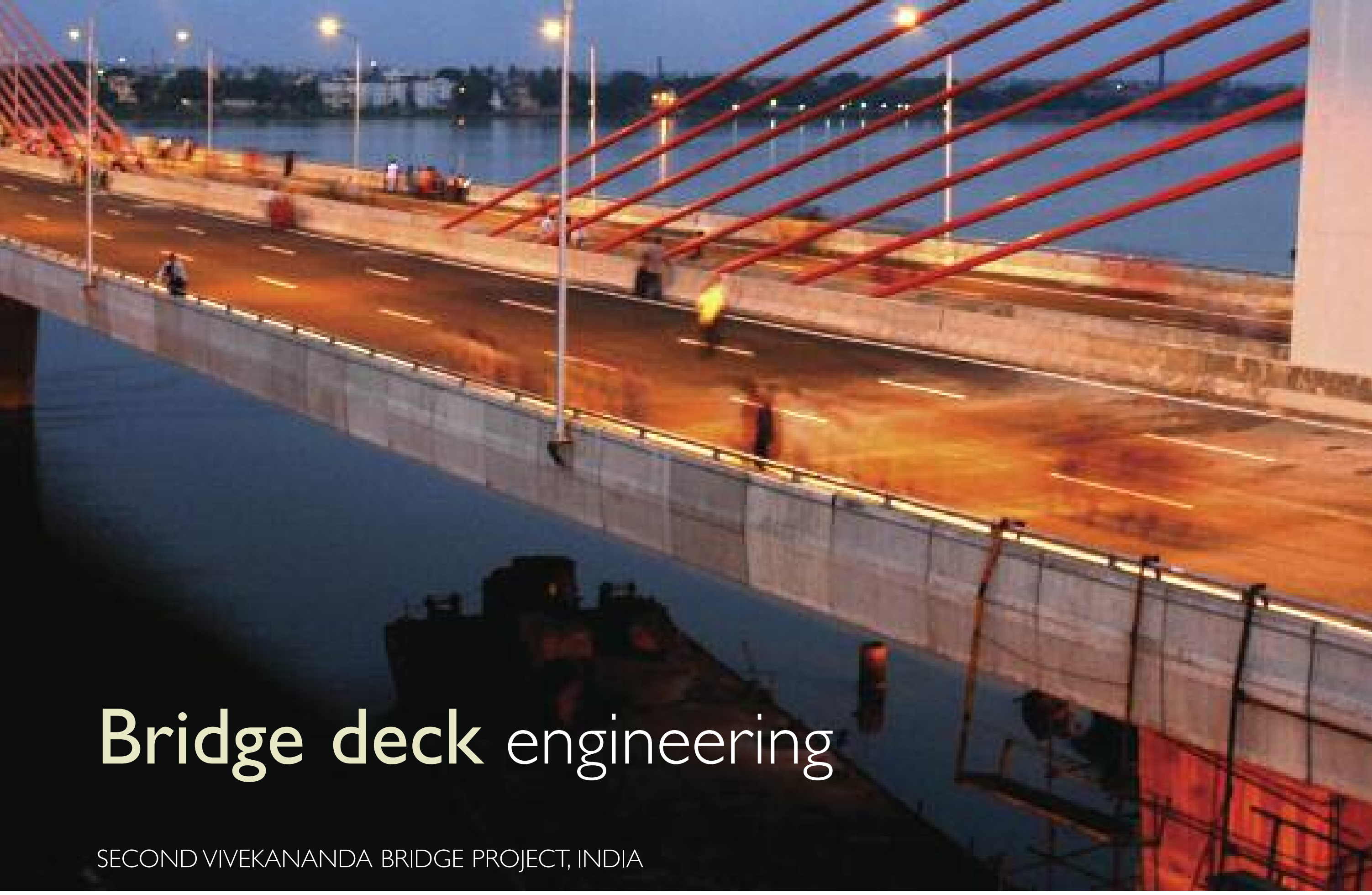
The Second Vivekananda Bridge near the Dakshineswar Temple, Kolkatta, West Bengal is India's first six lane, single plane supported extradosed bridge. Kamalakar Naidu, Regional Manager of **BBR (India) Pvt Ltd,** the BBR Network member in India, reports on the deck construction of the bridge and BBR's involvement.

The new bridge connects the NH2 / NH6 on Howrah side with the NH34 on the Kolkatta side. The 6.1 km bridge consists of an 880 m long main span, with a 1560 m long approach span on the Kolkata side and 3670 m of approach span on the Howrah side.

The total project cost was estimated at Rs.6,400 million. We were involved in the construction of the main span bridge where deck post-tensioning with the BBR CONA internal system was adopted.

BRIDGE OVERVIEW

The 880 m long main-span over the River Hoogly is a six lane segmental box structure, with seven spans of 110 m each and two end spans of 55 m. The bridge is a two span continuous structure having expansion joints every 220 m. The 28.6 m wide carriageway has permanent PT bars coupled through the main bridge along with internal and external tendons.



Bridge deck engineering

SECOND VIVEKANANDA BRIDGE PROJECT, INDIA

SEGMENT CASTING

A short-line precasting construction technique was implemented to concrete the 256 three meter wide segments. The casting bed was designed to cast various types of segments by hydraulically operated adjustable, detachable shuttering. A diverse range of post–tensioned ducts was provided for internal and external tendons – in a diagonal, longitudinal or transverse direction depending on requirements. After attaining the minimum specified concrete strength for the segment, one third of the transverse post-tensioned tendons were stressed to allow removal of the segment from the casting bed. Then, on attaining full strength, balance transverse tendons were stressed at the stock yard.

SEGMENT ERECTION

Two precast parts of the pylon / pier segments were positioned and fixed to the pier, making a monolithic structure. The stage-by-stage pylon construction was carried out simultaneously with segment erection, using balanced cantilever construction methods.

The segments were erected on either side of the pier with the help of movable form travelers placed over the pier segment. The erected segments were coupled with permanent post-tensioned bars and then glued with epoxy to the previous segments. Later, the permanent post-tensioned bars were stressed to allow the release of the form traveler.

After completing the tensioning of the internal PT tendons, the form traveler was moved to the next position to complete the process of segment erection until the final pour. A similar procedure was followed at the remaining pier locations and segment end joints are integrated to provide continuity for the main bridge. The long external PT tendons were connected and stressed to present the whole main span as an interlinked unit.

TEAM & TECHNOLOGY

OWNER NHAI
Second Vivekananda Bridge Toll Corporation
MAIN CONTRACTOR L&T-ECC Division
DESIGN / SUPERVISION CES-PB
TECHNOLOGY
BBR CONA internal
BBR CONA external
BBR NETWORK MEMBER
BBR (India) Pvt Ltd

Launching downhill

Halfway between the Mediterranean Sea and the Pyrenees and only seventy miles from Barcelona, two steel motorway bridges have been constructed. Gustavo Delgado Martín of **BBR PTE** – the BBR Network member in Spain – describes the innovative solution for composite steel bridges with a downward gradient.

The diversity of Cataluña's terrain, which alternates between very mountainous areas and plains, led the designers to choose the incremental launching method as their preferred construction method.

TWO BRIDGES

The Sant Andreu de la Vola bridge is a composite structure in Manlleu, Cataluña, on the Vic-Olot

TEAM & TECHNOLOGY (St Andreu de la Vola)
OWNER Generalitat GISA
MAIN CONTRACTOR
JV Tunel De Bracons (FCC + Guinovart)
DESIGNER Technical Services, FCC Construccion
TECHNOLOGY Launching
BBR NETWORK MEMBER BBR PTE (Spain)

motorway. It was built using the incremental launching method. The bridge deck is 156 m long, divided into four spans (33 m + 2 x 45 m + 33 m) with a gradient of 2.68%. The launching was executed downhill from the top abutment in two phases – the first one for a length of 75.5 m and the second one for a length of 80.5 m. The total weight to be launched downwards was 3826 kN.
Meanwhile, Eix del Llobregat bridge is a composite structure located in Puig-Reig, also in Cataluña, on the C-16 Barcelona-Puig Cerda motorway. The whole bridge was constructed by two methods:
- Installation by crane (340 m)
- Launching method (107 m)

The bridge deck launched was 107 m long, divided in two spans (60 m + 47 m) with a gradient of 1.00%. The launching was carried out downwards from the top abutment and in only one phase. The total weight launched was 7289 kN. The deck connection operation occurred approximately 16 m from the center pier.

LAUNCHING METHODOLOGY

Both bridges were launched with two heavy lifting pulling jacks and one heavy lifting retaining jack. We used the same equipment for both bridges. The pulling and retaining jacks have a capacity of 850 kN, with seven compacted steel strands and the stroke of each jack is 400 mm. With this stroke capacity, we reached launching speeds of seven meters per hour. All jacks were synchronized by means of programmable logic controllers. A retaining force was set and, once

ZARQA COLLEGE BRIDGE, JORDAN

Shaping a ...

This structure is located over the road connecting the capital city, Amman, with the second largest city in Jordan. Zarqa College Bridge is an overpass which passes above one of the busiest highways in Jordan.
The Zarqa College Bridge consists of two separate bridges, each one is 10.2 m wide and, due to local planning restrictions, Zarqa College Bridge had to have a 45 degree skew angle with 40 and 42.40 meter spans respectively.
For the design of this bridge, considerations of economy and aesthetics, as well as more practical matters relating to speedy construction, were of great importance. Accordingly, the designer came up with this innovative deck shape which allowed the whole 82.40 m of deck to be poured in one operation. The parabolic shape provided the aesthetic appeal and the skew angle – and

the pulling force reached the retaining force plus the friction force between the structure and the supports, the bridge started to move. The movement of the pulling jacks was synchronized in displacement. All the jacks were anchored to an auxiliary steel structure to the abutment, and the steel strands end in PT anchorages which were connected to the bridge by means of an auxiliary structure.
Launching was performed by sliding the bottom flanges of the two metal girders over temporary neoprene-teflon sliding bearings. These bearings were provided with longitudinal guides to prevent the bridge from decentering during launching.
The underside of the metal flanges was treated with a special paint to reduce friction and, for each launching phase, was lubricated in front of each bearing to prevent excessive friction.

TEAM & TECHNOLOGY (Eix del Llobregat)
OWNER CEDINSA
MAIN CONTRACTOR
JV Eix Bergueda
(FCC + COPCISA + COPISA + COMSA)
DESIGNER
CESMA + Technical Services, FCC Construccion
TECHNOLOGY Launching
BBR NETWORK MEMBER BBR PTE (Spain)

facilitated the single pouring operation which speeded the construction operation.
For BBR VT CONA CMI technology, this bridge represented a 'first' in Jordan for three reasons:

- the shape of the deck
- the use of 31 strands in each cable
- the construction with a European Approved (CE-marked) PT system

Both bridge decks were successfully completed in four months.

TEAM & TECHNOLOGY
OWNER Ministry of Public Works & Housing, Jordan
MAIN CONTRACTOR
Marwan Al Kurdi & Part.ners Co. Ltd
DESIGNER Troïs Engineering Ltd
TECHNOLOGY BBR VT CONA CMI internal
BBR NETWORK MEMBER
Marwan Al Kurdi & Partners Co. Ltd (Jordan)

Lateral Bridge Sliding

RINGWOOD RAIL BRIDGE, VICTORIA, AUSTRALIA

With new road systems being built, interfacing these with the existing infrastructure creates many challenges that require carefully engineered solutions. Mark Sinclair reports how **Structural Systems** – the BBR Network member in Australia – recently completed the sliding operations to move a new rail bridge into position in just a few hours, during a railway shutdown. This important rail bridge, located in Melbourne's Eastern Suburbs, was a crucial component in the US$ 2bn+ Eastlink project

TEAM & TECHNOLOGY

OWNER Eastlink

MAIN CONTRACTOR
Thiess John Holland

DESIGNER
CW-DC / Baigents & Structural Systems (launching system only)

TECHNOLOGY
BBR CONA internal
Bars
Launching

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

The new 39 km long Eastlink motorway runs from Donvale in the north to Frankston in the south via Dandenong, through Melbourne's Eastern suburbs. Where the new freeway meets the very busy existing Lilydale and Belgrave railway lines, a crossing was required. The existing twin track rail line was on an embankment and the proposed motorway was to pass underneath the live railway. The chosen solution was to build a new rail bridge adjacent to the tracks and slide it into position one weekend during a possession. The alternative – a road tunnel under the railway – was not possible because of the shallow depth available.

Structural Systems worked on several structures for this mammoth project which included complete substructure construction to selected bridges and specialist post-tensioning operations. At Ringwood, the rail bridge consists of twin steel structures of four simply supported spans, with a total length of 106 m. Each of the twin single track bridges has a weight of 920 t. Our works, under a separate package, involved the provision and stressing of ø 75 mm bars for ø 1800 mm piles, which connect through 17 m long 130 t precast headstocks – these were fitted in earlier rail possessions using a 500 t capacity crane. The five headstocks were post-tensioned on site, in stages to match the construction loadings.

DEVELOPING LAUNCH SYSTEM

Our expertise was sought to develop and operate the lateral launching system. The client's initial concept was to set up a frame with relocatable hydraulic jacks to ratchet along and push each of the two bridges individually into position. This required eight jacks acting in unison to launch the four spans of the first bridge, then these were set-up again to jack the second bridge. Our proposal was technically different, in that pulling tendons would be set up in five locations, with adjacent spans temporarily linked together – saving three jacking points – and the linking of both the single line bridges together, such that both bridges were launched simultaneously. Thiess John Holland, our client, was very supportive of this proposal as it saved a separate launching operation. The penalty costs for delaying the reopening of the railway were US$ 1,200 per minute!

DESIGN AND KIT

The design of the system was awarded to Structural Systems, and it incorporated the use of five large 145 t capacity 1.4 m stroke pulling jacks using ø 56 mm pulling tendons in 1.35 m modules. A separate pull back system was detailed should the need arise to correct for any jamming or misalignment during the main launch.

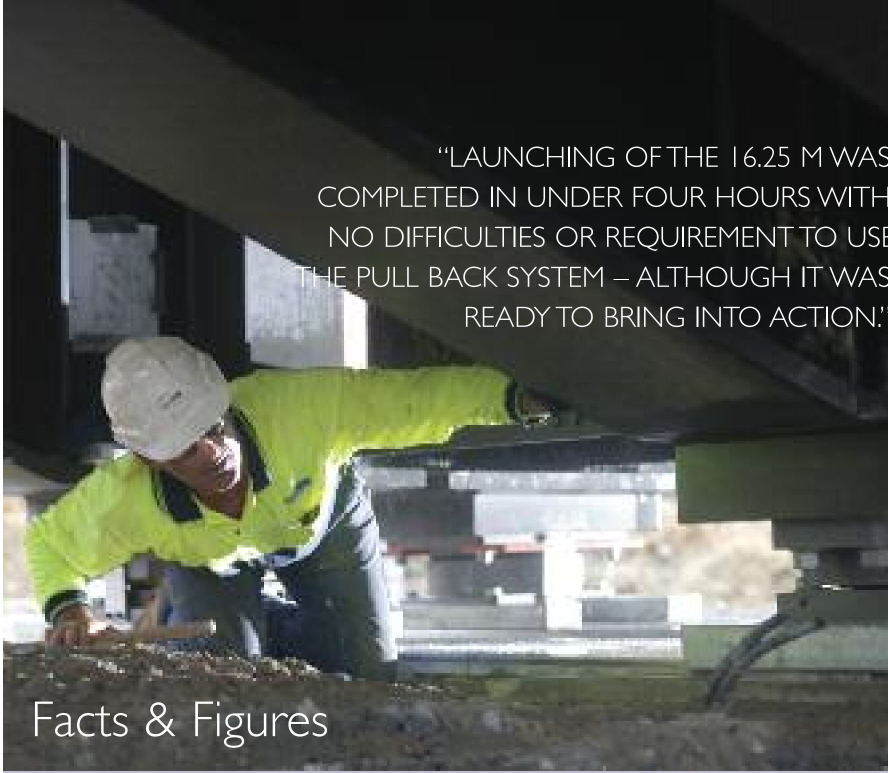
As part of the design package, temporary connection details were required to allow the steel bridge to connect to the launching system, but also to the substructure to allow for reaction of the jacking loads. Considerable detailed methodology was developed and reviewed by numerous parties, given the criticality of the launch and the high penalties should delays occur.

OPERATION PHASE

The operation phase was separately awarded to Structural Systems, and required two launches, which included a trial launch approximately one month ahead of the main launch. The trial launch of 3 m was to prove the reliability of many items, including the jacking system. Some adjustment to the sliding bearings was undertaken as their performance during the trial launch was marginal. A window of five hours was allocated for the launching process. In order to guarantee a trouble-free operation, spare jacks, a pump, generator, and specialist hydraulic service team were on site should they be required.

Like much of Australia, Melbourne was in drought until the weekend of the launch – when persistent rain was the order of the day. Some 8,000 m^3 of embankment was moved with a fleet of earth-moving gear and final preparations were completed to allow for the launching works.

Launching of the 16.25 m was completed in under four hours with no difficulties or requirement to use the pull back system – although it was ready to bring into action. Subsequent works were completed and the railway reopened comfortably ahead of schedule.



"LAUNCHING OF THE 16.25 M WAS COMPLETED IN UNDER FOUR HOURS WITH NO DIFFICULTIES OR REQUIREMENT TO USE THE PULL BACK SYSTEM – ALTHOUGH IT WAS READY TO BRING INTO ACTION."

Facts & Figures

Bridge sliding

- ◆ Twin 4 span simply supported steel bridge structures, total: 106 m
- ◆ Spans: 18.863 m, 37.212 m, 26.808 m & 23.850 m
- ◆ Total weight: 1,840 t (2 x 920 t)
- ◆ Slide distance: trial – 3 m, main launch – 16.25 m, total – 19.75 m
- ◆ Launch time: under 4 hours
- ◆ Equipment: 5 x 145 t x 1.4 m stroke jacks, 10-port isoflow pump
- ◆ Actual pulling forces: 143 kN to 284 kN (different nodes)

Post-tensioning tendons

- ◆ 20 – 15 or 20 x ø 15.2 strands
- ◆ 75 mm bars 4.0 m to 5.5 m long, minimum breaking load 4,311 kN
- ◆ Multi anchorages each end of the tendon 1506 & 2206
- ◆ Duct size: ø 95 / ø 105 mm

KAMPONG PANDAN FLYOVER, KUALA LUMPUR, MALAYSIA

Delivering certainty

Chang Chee Cheong, General Manager of **BBR Construction Systems** – the BBR Network member in Malaysia – describes how BBR technology and expertise delivered certainty for a critical highway flyover scheme in Kuala Lumpur where there were risks from interfaces with other projects.

This project was for the construction of a flyover above the existing Jalan Tun Razak bridge and roundabout. It connects the busy commercial area at Jalan Sultan Ismail with the housing area of Jalan Kampong Pandan and the scheme objectives were to improve traffic circulation and access to the roundabout.

CONSTRUCTION INTERFACES

At the same time, there were two other projects in progress – the SMART tunnel and KL-Putrajaya Highway Ramps. The original method of construction was detailed as precast segmental construction span-by-span, using an expensive overhead launching gantry. If the handing over of a pier were to be delayed due to other contractors, the launching gantry could not advance forward.

ELIMINATING RISK

By adopting an alternative design, based on balanced cantilever construction using form travelers, the sequence of construction could be changed according to availability of piers – giving the advantage of both flexibility and economics. BBR Malaysia, through the use of form travelers and prestressing technology, combined with CEPAS' finely-tuned and well-proven design expertise, optimized the design and construction method for the superstructure. The owner's requirements were to maintain the span lengths, shape and outer dimensions of the bridge superstructure.

BRIDGE SUPERSTRUCTURE

The flyover is a multi-span bridge structure consisting of 12 spans with an overall length of 568 m.

- Part A: 40 m + 56 m + 56 m + 40 m Total = 192 m
- Part B: 40 m + 56 m + 56 m +48 m + 40 m Total = 240 m
- Part C: 40 m + 56 m + 40 m Total = 136 m

Parts A and C were built using conventional staging over existing median. After stressing the longitudinal BBR CONA 1906 tendons, the strands were coupled using K-couplers to construct the next span. Part B was carried out using the balanced cantilever method because of the busy traffic at the roundabout and existing Tun Razak flyover.

The superstructure consists of two single cell box girders of varying depth from 3.2 m to 2.4 m. The two box girders are structurally independent of each other by a gap of 200 mm. Each box has a 9.45 m deck width, designed to carry two carriageways.

PRESTRESSED DIAPHRAGM CROSSHEAD ON SINGLE PIER

Due to site constraints and in order to minimize the interference with the existing traffic flow, most of the piers were formed by a single column with a wide crosshead. The prestressed crosshead is capable of carrying two single cell box girders which are monolithically connected to the crosshead.

This was made possible by combining the crosshead with the diaphragm. Transverse tendons, consisting of ten BBR CONA 1906 tendons, were provided to transfer the loads from each box girder to the single central pier. This prestressed diaphragm crosshead is also monolithic to the single pier. The top of pier was enlarged into a flare head which is aesthetically pleasing. Such a monolithic connection without bearings also fulfilled the stability requirements in the construction stages of the free cantilevering construction. ➔

Local insight:
Birth of a capital city

Bordered by mountains on three sides, Kuala Lumpur, or simply KL, is the capital of Malaysia – the name literally means 'muddy confluence' in Malay.

In the 1850s, tin mining rights were granted for this area at the confluence of the Klang and Gombak rivers. Just 150 years later, KL has grown from a small sleepy Chinese tin-mining village into a bustling metropolis with a population of 1.6 million.

Most of central KL has developed without any central planning whatsoever, so the streets in the older parts of town are extremely narrow, winding and congested. The architecture in this section is a unique colonial type, a hybrid of European and Chinese forms.

Since the early days, increasing numbers of travelers have discovered Kuala Lumpur – lured by the world's cheapest 5-star hotels, great shopping and even better food.

BALANCED CANTILEVER CONSTRUCTION AND SHARING BBR NETWORK RESOURCES

The balanced cantilever method is commonly used for spans from 100 to 250 m – so this case of 56 m span maximum is somewhat unusual. This is possible due to the peculiar circumstances of this project and the availability of travelers lent to us by our Singapore cousins – a very big THANK YOU to them. This is a fine example of the benefits of the international BBR Network – being able to share such resources.

In a typical tendon lay-out for free cantilevering construction, the cantilever tendons are usually stressed at one end only, depending on the construction cycle. The anchorages of the cantilever tendons are placed within the deck slab as close as possible to the web. The span bottom tendons are pulled through the ducts after the closure gap and anchored at blisters within the box.

The following types of prestressing tendons were used for the Kampong Pandan flyover:

◆ Cantilever tendons: BBR CONA 706

◆ Span tendons: BBR CONA 1206 and 1906

The construction was so flexible that a mixed construction method was chosen for piers P5 and P8 to speed up the work. The segment on one side was cast on temporary staging, while the segment on other side was completed using form travelers.

KEY BENEFITS AND ADVANTAGES

The key benefit of the prestressing technology has been to enable balanced cantilever construction which was a necessity here to ensure that there were no interruptions to the flow of busy traffic at the roundabout and on the flyover.

By combining tendons with form travelers, a flexible method of construction was used to construct the Kampong Pandan flyover in an efficient and timely manner, despite being in the midst of other ongoing projects. The prestressed diaphragm crosshead over a single pier to carry two box girders provided an elegant and effective way to carry the loads to the substructure.

TEAM & TECHNOLOGY

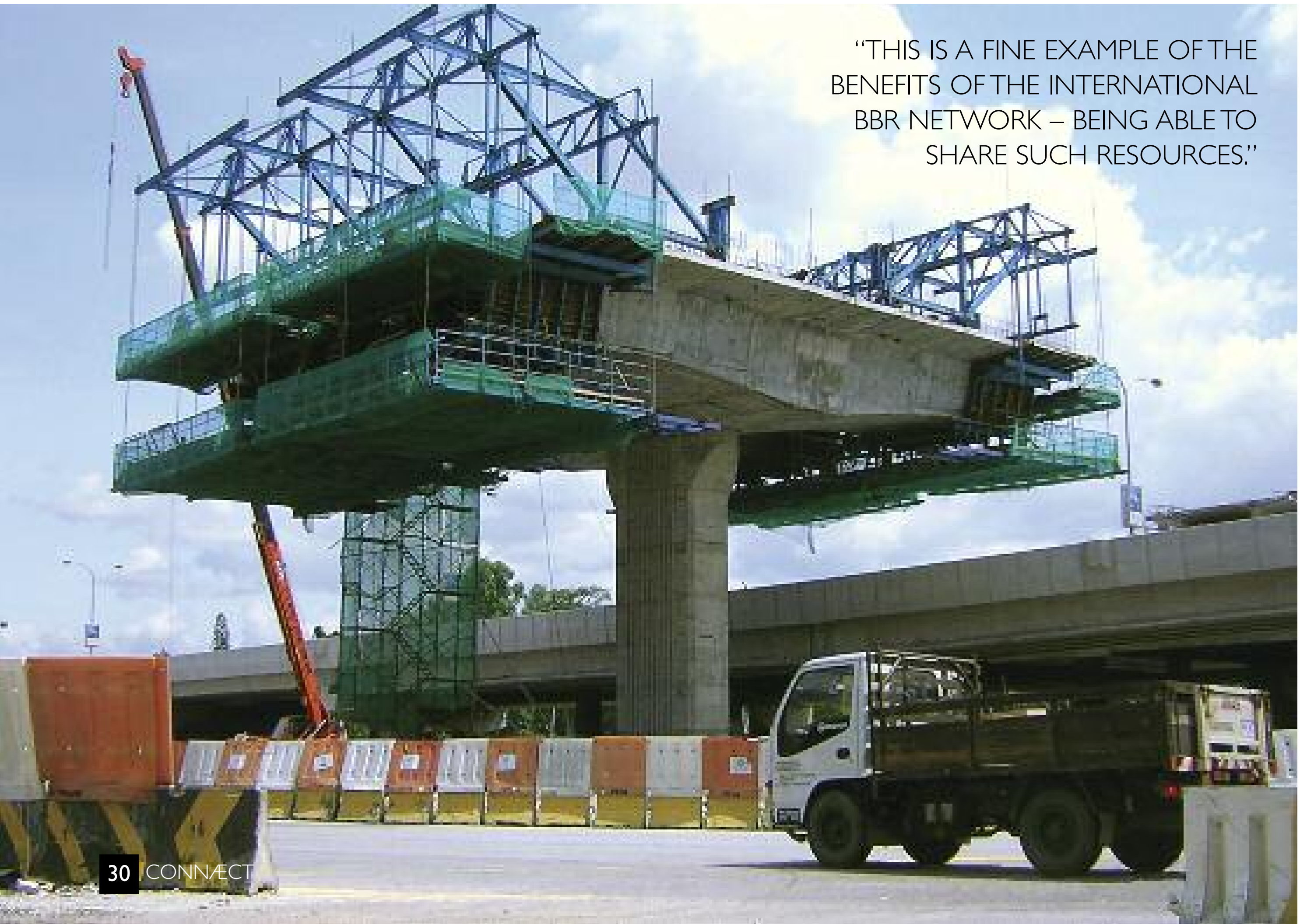
OWNER Public Works Department (Malaysia)

MAIN CONTRACTOR
Syarikat Muhibah Perniagaan & Perdagangan

DESIGNER CEPAS Plan AG

TECHNOLOGY BBR CONA internal
Balanced cantilever

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



"THIS IS A FINE EXAMPLE OF THE BENEFITS OF THE INTERNATIONAL BBR NETWORK – BEING ABLE TO SHARE SUCH RESOURCES."

The **real thing**

COCA COLA AMATIL STORAGE & DISTRIBUTION FACILITIES, SYDNEY, AUSTRALIA

Structural Systems – the BBR Network member in Australia – has been playing a major role in the realization of two state-of-the-art distribution centers for Coca Cola Amatil (CCA). The aim of CCA's 'Project Jupiter' is to consolidate and optimize the company's distribution. This state-of-the-art high-bay warehouse features a fully-automated materials handling solution which will cater for the bulk distribution needs of large retailers, while smaller customers, such as pubs and clubs, will be serviced by a new distribution centre at Eastern Creek. ➔

CCA currently has multiple-pick facilities and seven warehouses scattered around Sydney, covering over 125,000 m² of space. Project Jupiter will consolidate and significantly simplify the management of this process. The combined capacity of the two new facilities will reach 90,000 pallet positions – with room to expand.

“THE CONSTRUCTION METHODOLOGY RESULTED IN MINIMAL DISTURBANCE TO THE HAZARDOUS MATERIAL AND SAVED THE CONTRACTOR SIGNIFICANT REHABILITATION AND CONSOLIDATED WORKS.”

"IN ADDITION TO THE SAVINGS FOR CONSTRUCTION, THE POST-TENSIONED SLABS RESULTED IN LARGE JOINT-FREE SPACES AND ALSO PROVIDED EARLIER ACCESS FOR COMPLETION OF THE STRUCTURE."

Working closely with main contractor, Vaughan Constructions, Structural Systems has been implementing innovative post-tensioned solutions for CCA's new Northmead storage and distribution center, as well as their distribution center at Eastern Creek.

UNIQUE FACILITY

Shaun Sullivan reports that Structural Systems was awarded 5500 m^2 of suspended slab on ground in the internal and external staging areas for the 32 m high warehouse at Northmead, New South Wales – part of Coca Cola Amatil's premier manufacturing site in Sydney which boasts Australia's most advanced warehousing and distribution operation.

Constructed in two stages on an area of re-claimed land adjacent to a creek, the conforming reinforced solution required several meters of soil to be removed and then clean fill compacted in its place. As hazardous material, such as asbestos, was known to be in the sub-base soil, removal would have been time consuming – and its safe disposal had significant cost implications.

OUR SOLUTION

We were asked by the contractor, for an alternate post-tensioned solution. Using the BBR CONA flat 405 and 505 system, the slabs were cast directly over the ground yet supported on piles at 6-8 m centers throughout. The construction methodology resulted in minimal disturbance to the hazardous material and saved the contractor significant rehabilitation and consolidated works.

On normal suspended slabs, draped tendons are used between the columns, with the tendons fixed to the formwork to maintain the profile during the pour. As the ground acts as formwork for these slabs, draped tendons could not be used here, as there was no suitable material to which the tendons could be fixed. Thus, only tendons of minimal drape or a constant profile could be used. This presented several design challenges as some of the benefits of post-tensioning were lost.

AVOIDING CLASHES

The first stage of the post-tensioned slab was for the internal staging area used to support conveyors that service the twin masted crane. Due to the numerous post-fixed hold down bolts of the steel-framed conveyor, congestion in the top surface of the slab had to be kept to a minimum. Therefore, two layers of constant height tendons were used, with the first layer having tendons at orthogonal direction in the bottom and the second layer tendons in the top. This resulted in comparatively less reinforcement than the more conventional single layer of post-tensioning and consequently less potential for clashes with hold down bolts.

IN FOCUS: Coca Cola

The product that has given the world, arguably, its best-known taste was born in Atlanta, Georgia, on 8th May 1886.

Dr. John Stith Pemberton, a local pharmacist, produced the syrup for Coca-Cola®, and carried a jug of the new product down the street to Jacobs' Pharmacy. It was sampled, pronounced excellent and placed on sale for five cents a glass as a soda fountain drink – made by adding carbonated water to the new syrup.

Dr. Pemberton's partner and bookkeeper, Frank M. Robinson, suggested the name and penned the now famous trademark 'Coca-Cola' in his unique script.

The first newspaper advertisement for Coca-Cola soon appeared in The Atlanta Journal, inviting thirsty citizens to try "the new and popular soda fountain drink". Hand-painted oilcloth signs reading "Coca-Cola" appeared on store awnings.

Dr. Pemberton never realized the potential of the beverage he created. He gradually sold portions of his business to various partners and, just prior to his death in 1888, sold his remaining interest in Coca-Cola.

From the early beginnings when just nine drinks a day were served, Coca-Cola has grown to the world's most ubiquitous brand, with more than 1.4 billion beverage servings sold each day.

TEAM & TECHNOLOGY

OWNER
Coca Cola Amatil (Northmead)
Goodman International (Eastern Creek)

MAIN CONTRACTOR Vaughan Constructions Pty Ltd

DESIGNER
Structural Systems Limited (Northmead)
OPRA Architects and Costin & Roe Consulting Engineers (Eastern Creek)

TECHNOLOGY BBR CONA flat

BBR NETWORK MEMBER
Structural Systems Limited (Australia)

SPEED AND EFFICIENCY

The second stage was for the heavily loaded external staging areas, where trucks are loaded from the conveyor ready for shipping. The loading of this area had to cater for fully laden B-double trucks parked side-by-side. As there were no hold down bolts in this area, a single layer of constant height post-tensioning – central within the slab depth – was adopted for speed and efficiency. In addition to the savings for construction, the post-tensioned slabs resulted in large joint-free spaces and also provided earlier access for completion of the structure.

OVER AT EASTERN CREEK

Meanwhile, for CCA's new Eastern Creek distribution centre in Sydney's western suburbs, Structural Systems has successfully completed the design, supply and installation of over 28,000 m^2 of post-tensioned slab on grade for Goodman International Property Developers.

QUALITY FROM CONTROL

Using the bonded flat slab system again, the post-tensioned slabs were cast after the foundations, structural steel frame, roofing and pre-cast concrete cladding had been constructed. The stable environment – created by the completion of the structure – allows greater control of the concrete pouring and finishing that assists in achieving a high quality burnished (polished) surface.

INNOVATION

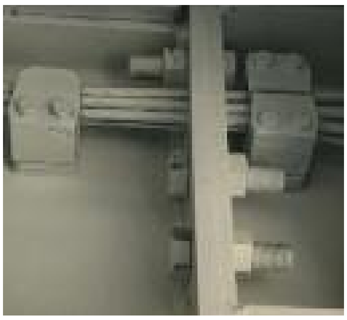
The use of innovative edge details – to eliminate pour strips, reduce construction costs and improve the surface finish of the floor – allowed the post-tensioned tendons to be stressed through the precast panels. The 28,000 m^2 of floor was divided into 14 pours and were completed in nine weeks.

Due to be operational in early 2009, the distribution centre will be a landmark in the field of green industrial buildings. ●

MULTI-LEVEL CAR PARK, PUNE, MAHARASTRA, INDIA

Indian first for PT with steel

External post-tensioning techniques for a prefabricated steel structure were adopted for the first time in India, reports Mr. Manjunath of **BBR (India) Pvt. Ltd** – the BBR Network member in India who designed, supplied and installed the post-tensioning system for this new multi-level car park.



Infosys Technologies Ltd urgently needed some 2200 car parking spaces for staff on their software development campus in Pune.

PREFAB STEEL STRUCTURE

To achieve the client's tight time schedule, the main contractor had decided upon a prefabricated structural steel frame system, with structural steel columns and beams, plus a cast-in-situ slab on steel decking.

The structure has an overall plan dimension of 95 m x 65 m, with nine 3.25 m high floors. ISUB – 600 steel beam sections were used for the main beam and ISUB – 400 for secondary beams. The entire structure was prefabricated and connected together using a bolted system.

PT INSTALLATION

The main contractor, in association with BBR (India) Pvt Ltd, sought to achieve lighter sections, increased grids spans – and, ultimately, cost savings – by taking advantage of post-tensioning technology.

For the main 64 m long beams, six BBR CONA external tendons of 12.7 mm diameter PE-coated strands are provided on either side of the web. For the 20 m, 30 m and 50 m long secondary beams, two tendons are provided on either side of the web.

The cable profile was maintained with help of prefabricated steel deviator blocks connected to the webs. Special prefabricated steel anchorage blocks were also developed to accommodate the barrel and wedge system to facilitate the stressing of strands using monostrand jacks.

STRESSING OPERATION

The four stage stressing was carried out by a BBR U-16 monostrand pulling jack. Before concreting the slab, 50% of design load was induced in two stages of 25% each. Props were introduced for the main and secondary beams and then the slab decks were cast. Next, the remaining 50% design load was induced in a further two stages of 25% each. The concrete was allowed to set for seven days and floor finishing was carried out later.

SUBSTANTIAL ECONOMIES

By adopting external post-tensioning technology for this steel design, the main contractor was able to reduce the materials requirement at critical locations which brought substantial economies in the overall steel structure.

TEAM & TECHNOLOGY

OWNER M/s Infosys Technologies Ltd
MAIN CONTRACTOR M/s Geodesic Technologies Pvt Ltd
DESIGNER M/s Geodesic Technologies Pvt Ltd
TECHNOLOGY BBR CONA external
BBR NETWORK MEMBER BBR (India) Pvt Ltd

RECYCLING PLANT, AUCKLAND, NEW ZEALAND

Towards **zero waste**

As environmental sustainability becomes increasingly important to people and businesses worldwide, Keith Snow of **BBR Contech** – the BBR Network member in New Zealand describes the creation of the most technologically advanced materials recovery facility (MRF) in the Southern Hemisphere.

Capable of sorting more than 80,000 tonnes of recyclable waste a year and converting more than 95% into reusable products, the new MRF is sited – appropriately – on top of a former landfill!

COLLABORATION & INNOVATION

Built to cater for the people of Auckland and Manukau cities, the facility is based on a 4000 m^2 post-tensioned slab floor – designed by New Zealand's BBR Contech in close collaboration with Structural Systems, its BBR Network counterpart in Australia. Together with main contractor Mainzeal Property and Construction, a solution was developed that copes with the weak and potentially unstable ground beneath the facility.

IDEAL FOR SOFT GROUND

The 200 mm thick slab is essentially suspended above the ground, supported by 128 steel piles driven into the rock underneath the former landfill. Created in four pours on-site, it has a sub-base of 100 mm diameter chunks of crushed concrete, which enables any gases rising from the landfill to escape freely – although not into the plant, as the floor's under-surfaces are lined with an impermeable polyethylene membrane. Meanwhile, the floor's elevation and suspended design enables the ground to settle with no impact on the MRF building and its operations.

Suspended floors like these are ideal for soft ground conditions as they enable businesses like the MRF to use land effectively for the long term.

STRONG & SLEEK

The post-tensioned floor is designed to cope with the MRF equipment and anticipated loads, which could increase to as much as 120,000 t of recyclable waste a year. Offering benefits of easy care and long-term durability, its smooth, joint-free surface makes it ideally suited to industrial and large commercial applications.

TEAM & TECHNOLOGY

OWNER Visy Recycling New Zealand
MAIN CONTRACTOR Mainzeal Property and Construction Ltd
CONSULTANT Day Consultants (structural engineer) BBR Contech (slab design)
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER BBR Contech (New Zealand)

OBEROI COMMERCIAL TOWER -1, MUMBAI, INDIA

BUILDINGS

Shaping the Mumbai skyline

A new landmark has arrived on the Mumbai skyline, reports Mr Manjunath, Regional Manager – Projects for **BBR (India) Pvt Ltd**, the BBR Network member in India.

The 32-storey Oberoi Tower – 1 project, in the city's Goregoan (E) district made famous by 'Bollywood', is the first of its kind and was completed in record time thanks to our specialised BBR technology.
BBR (India) Pvt Ltd was engaged for the design and preparation for the post-tensioning work and the supply, installation, stressing and grouting of the BBR CONA flat tendons.

TECHNICAL OVERVIEW

Office floors consist of a series of post-tensioned banded beams spanning from the inner core to the peripheral columns and the slab between them is spanned across a ribbed reinforced concrete slab.
To maximise floor heights and keep the building within the prescribed height overall, the floor system was changed to a post-tensioned flat plate solution for the hotel levels.

PT TECHNOLOGY

The BBR CONA flat system was used for post-tensioning the banded beams and typical flat plate slabs. The post-tensioned structure was a shallow depth band beam – the flat geometry has the advantage of allowing maximum eccentricity of the tendon in the shallow section.

EASE OF APPLICATION

The stressing kit for flat tendons is small and light – thus easy to handle and ideal for working with floor levels of different heights. The installation of flat tendons within the band beam reinforcement is also easier and the anchors are also smaller, making them well-suited to the limited depth of the beam or slab at the stressing edge.
The scheme's success has resulted in a further four projects of a similar type in the surrounding area.

TEAM & TECHNOLOGY

OWNER M/s Oberoi Constructions
MAIN CONTRACTOR L&T
ARCHITECT Hellmuth, Obata+Kassabaum, INC
STRUCTURAL ENGINEER
M/s Sterling Engineering Consultancy Services Pvt. Ltd
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER BBR (India) Pvt Ltd

FLOATING STADIUM, MARINA BAY, SINGAPORE

Vibrant gem by the bay

With a seating capacity of 30,000 people, the Marina Bay Floating Stadium – next to the Esplanade – Theatres on the Bay, in Singapore – will be the venue for major events on the waters of Marina Bay until 2012.

With the closure of the National Stadium, the Singapore Government decided that this temporary stadium would be a cost-effective solution.
The five storey stand consists of 30 segments and five 4 m wide pourstrips. The stand was designed with a post-tensioned one-way beam slab scheme across spans between 8 m and 11 m. The whole viewing gallery is supported on reinforced concrete columns. Beam dimension varies between 0.2 m – 0.25 m wide by 0.4 m to 0.6 m deep. Four strand ducts were used in a typical beam.
As well as the annual National Day Parade, the Grandstand provided spectator seating for the inaugural night race of the Formula One motor racing series that was held in Singapore last September – putting it in the spotlight of world attention.

TEAM & TECHNOLOGY

OWNER URA / Spore Sports Council
MAIN CONTRACTOR
China Construction (South Pacific) Development
CONSULTANT De Consultants (S)
TECHNOLOGY BBR CONA internal
BBR NETWORK MEMBER
BBR Construction Systems Pte Ltd (Singapore)

Proof of PT versatility

BURJUMAN CENTRE EXTENSION,
DUBAI, UNITED ARAB EMIRATES

Warwick Ironmonger describes the successful contribution of his company, **NASA (BBR) Structural Systems LLC,** the BBR Network member based in the United Arab Emirates, in providing a complete design, supply and construct package for the post-tensioned floor systems for the mixed-use Burjuman Centre Extension project.

Located in the heart of Dubai, this 162,000 m^2 scheme consists of 4.5 floors of retail podium, a 29-storey office tower and two apartment towers of 21- and 25-storeys. Post-tensioned floor systems were used throughout each of these structures.

RETAIL LEVELS

Post-tensioned band beams and slabs were provided throughout the retail levels to achieve economy and offer a minimum depth solution that could deal with the significant loads and spans which ranged from 8.8 m to in excess of 16 m, transfer the numerous 'floating' columns, and cater for the varied and complex floor geometry. The irregular column positions between floors and the combination of steel composite columns supporting the overlying steel and glass atrium roofs were meticulously integrated into the post-tensioned design. The podium levels, approximately 250 m x 85 m in plan, were each split into ten different slab areas using a variety of corbel and dowelled movement joints – with a total of 18 individual concrete pours per floor. Each retail floor was comprised of a mixture of flat slabs, ribbed slabs, one-way slabs supported by band beams and transfer beams – all post-tensioned to achieve open plan retail areas.

OFFICE TOWER

The supports to the elliptical shaped 29-storey office tower consisted of only a central core and perimeter columns. A post-tensioned solution was implemented whereby 450 mm deep post-tensioned ribbed beams spanned the 10 m between the central core and perimeter post-tensioned beams which, in turn, spanned between the perimeter columns. The post-tensioning was used most effectively to support the 6.5 m long cantilevers at each end of the building creating the illusion of the structure floating in the air and to permit column-free office space on each of the typical floors.

APARTMENT TOWERS

The luxury apartment blocks, above the retail levels, each have 525-800 mm deep post-tensioned beams, spanning 8.5-12.5 m between cores and intermediate shear walls to support the 150-200 mm deep conventionally reinforced concrete slabs spanning between the beams. The successful application of the BBR CONA flat post-tensioning system to solve the many structural challenges that resulted from the ambitious architectural plans for this mixed-use project is a testament to the versatility of post-tensioning and the expertise of both Structural Systems and the wider BBR Network.

TEAM & TECHNOLOGY

OWNER Al Ghurair Group, Dubai, UAE
MAIN CONTRACTOR Al Habtoor Murray & Roberts, Dubai, UAE
DESIGNER Buro Happold / Dar Al Handasah, Dubai, UAE
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER
NASA (BBR) Structural Systems LLC (United Arab Emirates)

SPORTS ARENA, ŁÓDZ, POLAND

BBR Polska – the BBR Network member in Poland – has completed an extraordinary post-tensioning task. Site Engineer, M. Sc. Bartosz Łukijaniuk explains how a massive post-tensioned roof ring – needed to support the dome-shaped roof of the new sports arena in Łódz – was constructed.

Ring of **confidence**

The City of Łódz Office had decided to build a new 10,000-seat sporting and entertainment venue within the complex of one of the city's sports clubs – Łódzki Klub Sportowy. The arena is adjacent to the existing football stadium which is home to the former Polish football league champions.

THE BUILDING

The round sports hall has a concrete structure with a steel roof and steel cover wall. The arena level is approximately six meters below the surrounding ground level. The hall is surrounded with a type of moat, over which there are bridges leading to the entrances. Inside, will be the main arena plus all the usual facilities – and a full size basketball court.

The roof of this huge arena is supported by a post-tensioned concrete ring – an icon of modern engineering techniques, constructed by BBR Polska.

THE BRIEF

Our brief was to evaluate the detailed design for tendon layout and the bearing system for the roof ring, as well as for carrying out the work which included delivery of stressing system components, plus the complex post-tensioning of the roof ring and delivery and installation of the bearings. In addition, we undertook further complex works for a post-tensioned beam.

THE RING

The roof support ring rests on 16 concrete columns (spaced every 26 m) at around 15 m above arena level. It is a massive concrete structure which, in cross-section, is a concrete box – shaped like a leaning rectangle with 0.5 m thick walls. On the outer side of the ➔

roof ring, there is a huge 'gutter' made of prefabricated concrete elements – permanently fixed to the ring structure. The box is strengthened with cross-walls every eight meters, where steel roof girders are supported on the ring.

THE TENDONS

The box-shaped concrete structure of the ring is post tensioned with 28 BBR CONA 1906 internal tendons (72 t of strands) and 88 BBR CONA 706 external tendons (12 t of strands).

The internal tendons – spaced equally on the cross-section of the ring, with seven tendons in one section – take horizontal forces from main loads (dead loads), while external tendons – placed in appropriate numbers wherever needed, as dictated by the bending moments diagram – take bending moments from excess loads.

Because the ring is so very long, it is divided into four quarters – resulting in an internal tendon length of around 120 m. The internal tendons are anchored in four specially designed anchor blocks inside the ring. The external tendons are anchored in cross-walls – the longest tendon was some 25 m long.

THE BEARING SYSTEM

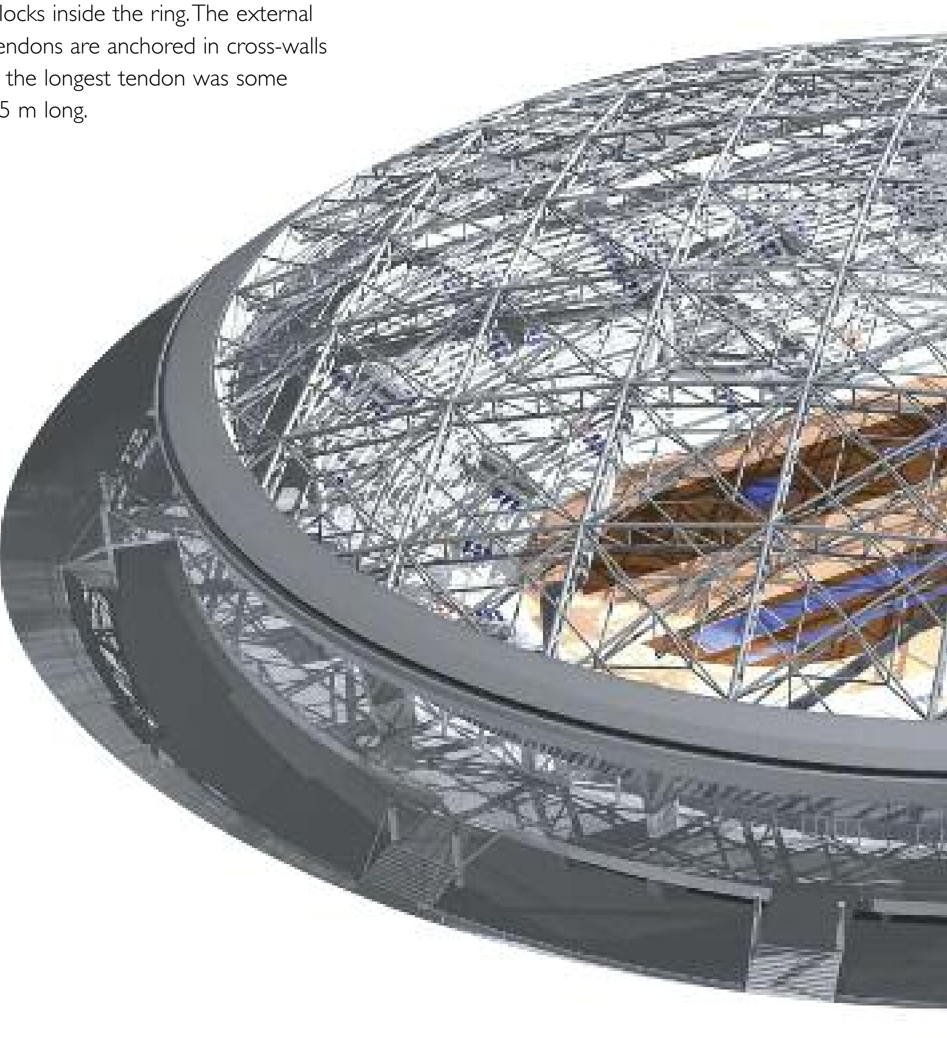
The bearing system involved the installation of 64 elastomeric bearings and 16 specially designed steel directional slide bearings. The system has a set of five bearings on each column – four elastomeric slide bearings and one steel guided slide bearing. The elastomeric bearings transfer vertical load from the ring to the column, allowing movement in all directions. Meanwhile, the steel guided bearings take horizontal forces and allow radial movement – blocking forces from any other direction to prevent unequal deformation of the ring.

The ring structure was concreted in stages – first the bottom slab, then side walls, next cross-walls and lastly, the top slab. Strands were pushed into ducts after the concreting process was finished.

THE PT SEQUENCE

The post-tensioning sequence assumed that first all internal tendons were tensioned. Then, we started tensioning all external tendons. The round shape of the structure meant that it was extremely important to apply stressing force equally around the perimeter, as well as on the cross-section of the ring. Therefore, we used two stressing sets which operated on opposite sides of the ring.

Due to high values of loss of stressing force – because of friction on curves – it was necessary



“BBR POLSKA COMPLETED THE WORK WITH A HIGH STANDARD OF PROFESSIONALISM AND TO A HIGH TECHNICAL STANDARD ....”
CITY OF ŁÓDZ OFFICE

to stress all internal tendons from both ends. This all resulted in much time and effort being spent on moving and preparing the stressing sets and operations.
The stressing sequence of the external tendons was also developed so that equal stressing force was applied to the structure.
All the work inside the ring box was carried out by hand – it was not possible to use a crane as there were no openings in the top of the ring structure and cross-walls precluded the use of a small crane to operate inside the ring box.

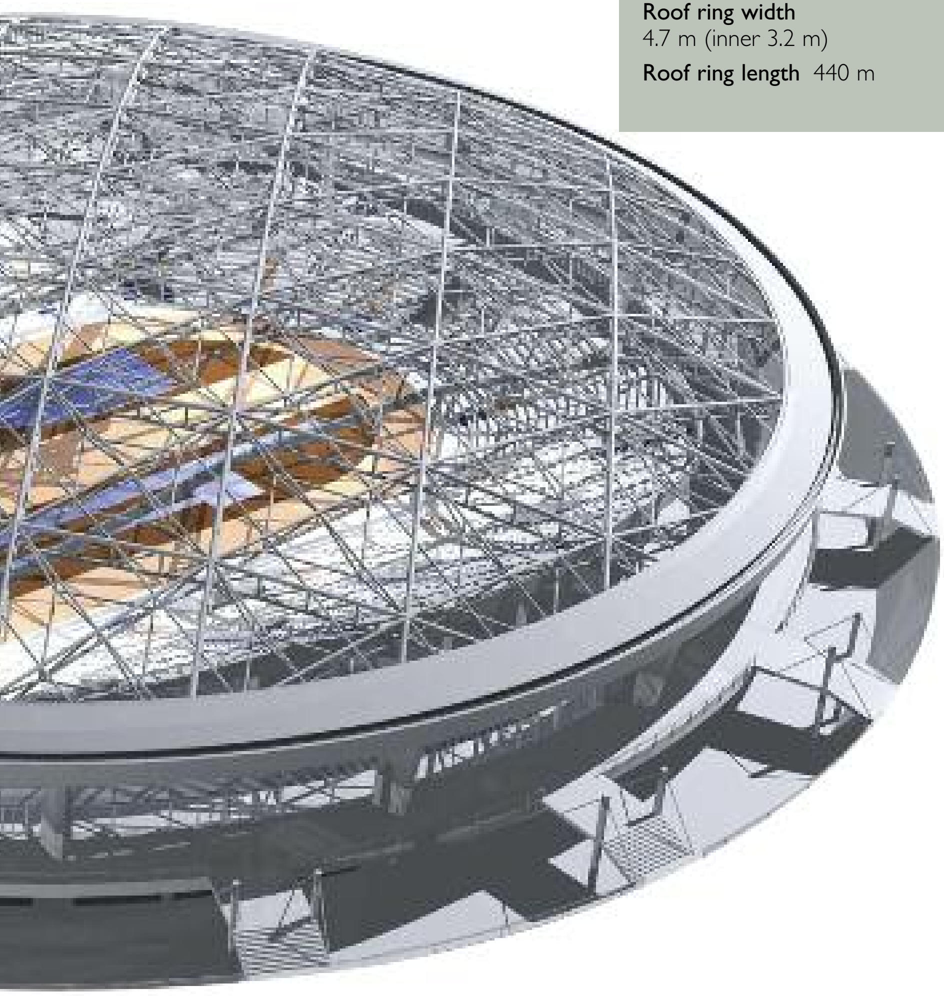
THE BEAM

The 25 m span post tensioned beam supports a floor slab. The development of a basketball court meant that a few columns were replaced with hangers attached to the beam – originally these were support only to the girders for the arena seating. The high loads and low acceptable deflection indicated that a PT beam was the only solution. The beam was post tensioned with six BBR VT CONA CMI 1206 tendons (3 t of strands).

This extremely demanding post-tensioning task was finished in May 2008 – two weeks ahead of schedule. This superb result is due largely to the excellent working relationships which developed between the BBR Polska team and the main contractor.
Investor satisfaction is a priority for us – and the reference letter received from our client, the City of Łódz Office, was a great reward for our efforts. This was the first time that BBR Polska had executed such a challenging and unusual stressing operation – we are looking forward to post-tensioning another stadium soon!

Facts & Figures

Arena area 14,500 m^2
Arena volume 385,000 m^3
Arena radius 70 m
Arena height 36 m
Domed roof diameter
140 m
Weight of roof structure
1,500 t
Roof ring height
3.7 m (inner 2.5 m)
Roof ring width
4.7 m (inner 3.2 m)
Roof ring length 440 m

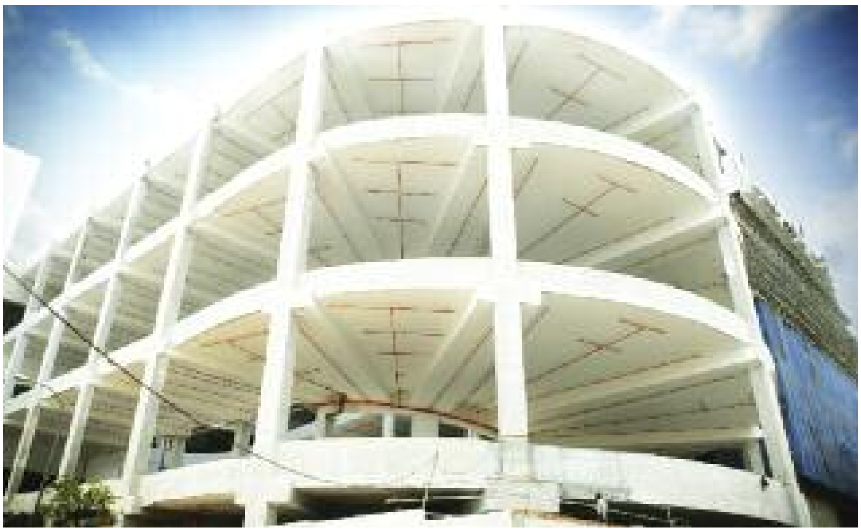


TEAM & TECHNOLOGY
OWNER City of Łódz Office
CONTRACTOR Skanska S.A.
DESIGNER ATJ Archikekci / KiP Sp. z o.o.
TECHNOLOGY
BBR CONA internal
BBR CONA external
BBR VT CONA CMI internal
BBR NETWORK MEMBER
BBR Polska Sp. z o.o. (Poland)

Located in the industrial region in the western part of Singapore, this development consists of six storeys, with two mezzanine floors and ancillary office. Miss Foo from **BBR Construction Systems Pte Ltd,** the BBR Network member in Singapore, takes up the story.

Race against time

Divided into two phases, Phase 1 includes half of the warehouse area, driveway, loading / unloading bay and ramp. The other half of the warehouse area, office and roof, together make up Phase 2. The loading / unloading bay and the ramp are located right in the centre, flanked by the warehouse area on both sides. The special feature of this building is that there are ramps and loading / unloading bays on every level – enabling easy access to the warehouse area, especially for heavy vehicles. Post-tensioning was used to construct almost the entire building.



PROJECT DETAILS

The post-tensioned flat slab thickness for the warehouse area is typically 330 mm for an 11 m by 11 m grid, with 700 mm thick drop panels. For the sixth storey, the flat slab thickness is 380 mm with 750 mm thick drop panels. Typical loading for the second to fifth storey warehouse area is 20.0 kN/m^2 (live) and 0.3 kN/m^2 (superimposed dead). The machinery to be placed in the sixth storey warehouse area is heavier, hence the loading there is significantly higher at 30 kN/m^2 (live) and 1.8 kN/m^2 (superimposed dead). The strength of concrete used in the design is 35 N/mm^2. The arrangement of the tendons is such that it is banded and distributed in both directions, as required by the consultant. Tendon spacing varies between 300-400 mm for column strips and 1000-1250 mm for middle strips.

TIGHT SCHEDULE

To meet the owner's requirements, Phase 1 is scheduled for completion before Phase 2. Hence, the race against time started right from Day One. One of the great advantages of using post-tensioning for flat slabs comes into full play here – enhanced construction speed. The usage of post-tensioning facilitates the earlier removal of form-work, resulting in a shorter floor-to-floor cycle time, thus reducing the construction time significantly. This enabled a smooth handover of Phase 1, meeting the time challenge set by the client. With the BBR post-tensioning system in place, the high performance and effective floor slabs create a smooth appearance, with a minimal number of joints – in addition to other value-added benefits, such as long-term durability and low maintenance.

TEAM & TECHNOLOGY

OWNER Ascendas

MAIN CONTRACTOR
Jian Huang Construction Co Pte Ltd

DESIGNER Tham & Wong Consultant

TECHNOLOGY
BBR CONA internal
BBR CONA flat

BBR NETWORK MEMBER
BBR Construction Systems Pte Ltd (Singapore)

THE LOFTS, BURJ DUBAI DEVELOPMENT, UNITED ARAB EMIRATES

Hidden **strength**

The Lofts project is part of EMAAR Properties' prestigious Burj Dubai Development – home of the world's tallest structure, the Burj Dubai. Warwick Ironmonger of BBR Network member **NASA (BBR) Structural Systems** reports on his company's involvement in the project.

This significant part of the Burj Dubai Development consists of nine podium levels, covering an area of approximately 160 m x 60 m, providing a common area and linking the three residential towers which rise out of the podium for a further 30 floors forming 'The Lofts'. The top four podium levels and all of the tower floors were post-tensioned by NASA Structural Systems.

We were responsible for the design and construction of the post-tensioned slabs, including the structural floor design, the supply of specialist materials and equipment, together with the post-tensioning shop drawings, installation, stressing and grouting of the tendons.

The top four podium floors and all of the tower floors were based upon 3 m floor-to-floor heights, making it virtually essential to adopt a flat plate construction of the floor slabs to maximize floor-to-ceiling heights.

The use of BBR CONA flat post-tensioning offered an economical solution for this type of floor system and assisted the construction progress to ensure the earliest possible completion of the structure.

The PT floor system also made it possible to support the large transfer loads – from the two pool structures on the uppermost podium level – without the need for deep transfer beams. The inclusion of post-tensioning allowed slab thickenings to be utilized in the pool support structure, and ensured the usability of the floors immediately below the pool support structure was not compromised.

Throughout the project, Structural Systems actively contributed to the main contractor's 'Don't Walk By' safety initiative, effectively creating and maintaining a safe working environment.

TEAM & TECHNOLOGY

OWNER
EMAAR Properties, Dubai-UAE

MAIN CONTRACTOR
Al-Futtaim Carillion LLC, Dubai-UAE

DESIGNER NORR, Dubai, UAE

TECHNOLOGY BBR CONA flat

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

CLANCY QUAY, DUBLIN, IRELAND

Canalside **innovation**

Clancy Quay is a mixed-use development located in Dublin City. **Structural Systems (UK) Ltd** – the BBR Network member in the UK – was awarded the contract for 20,000 m^2 of PT slabs based on an alternative proposal to the existing reinforced concrete scheme.

The project consists of an underground 200 mm car park slab and a ground level 600 mm transfer slab, supporting seven levels of superstructure on a 7.5 m square grid. Pre-cast construction, utilised in the superstructure of the five residential blocks, resulted in substantial transfer loadings at ground floor level.

Local planning regulations dictated a drained underground car park – hence the top surface of the car park slab is laid to falls. Reinforced concrete slabs would have required complicated setting out of the top reinforcement mat. The PT system removes this complication by varying the highest chair heights along the column lines to the required surface level.

The key factor in securing this project was the comparative savings offered over the reinforced concrete scheme. Reducing the excavation by 300 mm on a site with a high water table was also beneficial to the building works.

TEAM & TECHNOLOGY

OWNER Clancy Quay Developments

MAIN CONTRACTOR P Elliot & Company

TECHNOLOGY BBR CONA flat

BBR NETWORK MEMBER
Structural Systems (UK) Ltd

Largest joint-free PT slab

One of New Zealand's leading courier, logistics and distribution companies is to operate from a brand-new distribution centre in Auckland. CourierPost's new depot will be located in a 20,000 m^2 warehouse building at Highbrook Business Park in East Tamaki – which features what's thought to be the world's largest joint-free post-tensioned floor slab – designed and installed by **BBR Contech.** Terry Palmer and Jeff Marchant describe this latest project.

BUSINESS PARK WAREHOUSE, AUCKLAND, NEW ZEALAND

THE DISTRIBUTION SOLUTION

Created with eight pours over two months, the floor was designed in response to CourierPost's concerns about locating a conveyor belt over a joint, with inherent risks of slab shrinkage causing the concrete to split underneath, potentially damaging the machine. The company sought a smooth, blemish-free surface that would perform not only for the machines but also for the 180 courier vans expected to park, load and unload at the depot.

Working with business park developer Goodman Ltd, main contractor Dominion Construction and engineers MSC Consulting, the BBR Contech team designed a solution in which multiple pours were coupled together, effectively creating a single, continuous slab with no movement joints. Completed in December 2008, the CourierPost building is a model of BBR Contech ingenuity – a simple, highly effective solution to a potentially damaging issue.

TEAM & TECHNOLOGY

OWNER Goodman Ltd

MAIN CONTRACTOR Dominion Construction Ltd

DESIGNER
MSC Consulting Group Ltd (structural engineer)
BBR Contech (slab design)

TECHNOLOGY BBR CONA flat

BBR NETWORK MEMBER
BBR Contech (New Zealand)

RADISSON SAS HOTEL, DUBROVNIK, CROATIA

An architect's dream

Radisson SAS, the worldwide chain of hotels, is planning to open a new resort on the Adriatic Sea coast in the historic city of Dubrovnik – a UNESCO World Heritage Site. BBR Network member **BBR Adria d.d.** was commissioned to provide and install BBR tendons for 11 slabs which cover an area of more than 35,000 m^2. Despite the complexities of the structure, many supporting beams could be eliminated by the use of PT technology – and this allowed more freedom of design for the architect.

TEAM & TECHNOLOGY

OWNER Dubrovacki Vrtovi Sunca d.d.

MAIN CONTRACTOR Hidrocommerce d.o.o.

CONSULTANT I. Fabijanovic, B.Sc. Civ. Eng.

TECHNOLOGY
BBR VT CONA CMI internal
BBR CONA unbonded

BBR NETWORK MEMBER BBR Adria d.d.

Towering technology

Juan Linero and Gustavo Delgado of **BBR PTE** – the BBR Network member in Spain – report on how BBR technology has contributed to the creating of this 250 m high, state-of-the-art tower.

The Caja Madrid tower is located at the Paseo de la Castellana, in Madrid, close to the former training facilities of the Real Madrid soccer team. It belongs to the Spanish bank, Caja Madrid, and is part of the new business area being developed on the northern side of the city.

The building's structure is comprised of two reinforced concrete cores connected to each other at three different levels by two steel trusses which also bear the weight of the twelve floors above them. The loads are, therefore, transfered to the two cores which ultimately carry the weight of the whole tower down to the foundations.

Different BBR solutions have been applied to this project – such as multiple strand tendons, stressed bars with diameters of up to 75 mm or SWIF couplers for rebars. Addditionally, based on the pair strand / wedge technique, a number of complex heavy-lifting operations have been performed.

The post-tensioning technology has primarily been applied in two different areas – the main trusses and the core slabs.

The high altitudes, as well as the core construction method, posed major challenges for the post-tensioning activities – as a result, innovative systems had to be conceived. Thus, for the shortest tendons, the lack of space dictated that the strands should be cut on the ground, lifted by crane and pushed into the sheaths by hand, one at a time. For the longest ones, the pushing machine had to be placed in the only spot available, guiding the strand through PE flexible pipe down to the plate front.

For stressing the strands, jacks weighing 1000 kg were used. However, the unavailability of a crane added to the challenges, the engineers had to come up with a different approach to raising the jacks – temporary support beams connected to the sliding formwork above.

The BBR team faced yet another challenge in the installation and stressing of the bars. Since the space was limited, very small cylinders were used, requiring very high pressures – up to 1200 bar – in order to attain the 2400 kN necessary.

HEAVY LIFTING

The heavy lifting operations far exceeded the complexity of the previous tasks. In fact, the upper structure linking the two concrete cores could only be built 35 m below – and had to be lifted into its final position, 250 m above ground level. Four hydraulic jacks were placed on cantilevered decks connected to the top of the cores. First of all, the structure had to be slightly elevated in order to finish the assembly of the last parts. Once completed, the whole structure had to be raised to the top.

Despite the hazards and difficulties, BBR technology and its qualified staff provided the client with practical solutions which played a significant role in delivering this project at a minimum cost.

TEAM & TECHNOLOGY

OWNER Caja Madrid Bank

MAIN CONTRACTOR
FCC CONSTRUCCION, S.A. – Dragados JV

ARCHITECT Foster & Partners

STRUCTURAL ENGINEER
Halvorson and Partners

TECHNOLOGY SWIF
BBR CONA internal
Heavy lifting

BBR NETWORK MEMBER
BBR PTE (Spain)

CAJA MADRID TOWER, SPAIN

Green and lean

NEW COMMONWEALTH BANK CAMPUS, SYDNEY, AUSTRALIA

The New Commonwealth Bank Campus Project is the newest office development in the business district of the Sydney Olympic Park venue in Homebush Bay. Paul Maleszka of **Structural Systems** explains how the New Commonwealth Bank Campus is set to be one of the most sought after office spaces in the region.

The Campus Project is being developed by Colonial First State funds, Commonwealth Property Fund and Direct Property Investment Fund. This fast growing area is attracting the high end clients wanting a modern space with excellent facilities outside the crowded Sydney CBD.

REDUCING IMPACT

Reducing the impact on the environment is a highly sought after and marketable aspect. Bovis Lend Lease designed, project managed and constructed the New Commonwealth Bank Campus project with the environment in mind. The project has been registered for a Green Star – Office Design and Office As Built, rating with the Green Building Council of Australia (GBCA). Structural Systems assisted in reducing the environmental impact by using the BBR CONA flat bonded system which reduces the amount of new materials, such as concrete and reinforcement, compared to conventionally reinforced structures.

COST SAVINGS

The office space itself comprised five basement levels, podium, and two towers with eight levels each. Overall, the structure has 66,000 m^2 of stressed area. Originally, we were only engaged to supply and install the post-tensioning with a structural consultant designing and detailing. With our vast experience in design and detailing, Bovis Lend Lease requested us to design the very difficult transfer / podium level, as well as to advise on the upper levels in an effort to reduce costs. This resulted in an overall saving of 76 t of post-tensioning and 290 t of conventional reinforcement. This represented savings for the project of approximately 18% of the total post-tensioning and 36% of the reinforcement over the entire horizontal area.

These savings were not at the expense of any additional concrete or impacting on the tight deflection limits set for this high class structure. Installation time of the reinforcement and post-tensioning was also reduced, giving additional benefits to the builder. Overall, the engagement of Structural Systems and use of BBR CONA flat bonded systems helped deliver a more efficient structure with less impact on the environment – while still performing to the highest standards.

TEAM & TECHNOLOGY

OWNER Colonial First State Global Asset Management
MAIN CONTRACTOR Bovis Lend Lease
DESIGNER Connell Wagner
TECHNOLOGY BBR CONA flat
BBR NETWORK MEMBER
Structural Systems Limited (Australia)

Superior storage solutions

Site engineer, M.Sc. Bartosz Łukijaniuk of **BBR Polska Sp. z o.o.** – the BBR Network member in Poland – reports that his company has successfully completed the post-tensioning of two major silos in Poland – this sugar silo in Kruszwica and a clinker silo at the Kujawy Cement Plant. ➔

"THE SILO IS ABLE TO HOLD 60,000 T OF SUGAR – PUTTING THIS SILO AMONG THE LARGEST SUGAR SILOS IN POLAND!"

These are the fifth and sixth silo projects to be completed in Poland by BBR Polska Sp. z o.o. and both structures were completed in co-operation with Chemadex S.A. – a civil engineering and construction company which specializes in this type of work.

KRUSZWICA SUGAR SILO

National sugar producer, Krajowa Spółka Cukrowa S.A. needed to construct a new sugar silo as part of the modernization of their sugar factory in Kruszwica. Detailed design was carried out by Chemadex S.A. – who was also the main contractor for the project.

The concrete walls of the circular silo are 42 m high and the inner diameter is 47 m, while the wall has a constant thickness of 0.32 m. Both the foundations and bottom slab were concreted using traditional stationary formwork – the walls were slipformed. The whole silo is topped with a dome-shaped steel roof. The silo is able to hold 60,000 t of sugar – putting this silo among the largest sugar silos in Poland!

The silo walls are post-tensioned with horizontal BBR VT CONA CMI 406 and 706 tendons, anchored in four buttresses.

Sixty four BBR VT CONA CMI 406 tendons and 122 BBR VT CONA CMI 706 tendons were installed in the silo walls. Together, the strand weighed 88 t and in total we pushed about 75 km of strand into ducts.

The work, which was carried out from movable platforms, was completed in about 40 days.

KUJAWY CLINKER SILO

A new clinker silo has been built as part of a development at Lafarge Cement's Kujawy cement plant. The design was completed by the Stuttgart-based firm, Peter und Lochner and the main contractor was Chemadex S.A.

The concrete silo walls are 37 m high, 55 m in diameter and 1.2 m thick at the base and 0.45 m at the top. As with the sugar silo, the walls were slipformed. This silo is covered with a cone-shaped steel roof – the overall height of the silo is 69 m – and it can hold 120,000 t of clinker.

The walls are post-tensioned with 222 horizontal tendons anchored in six buttresses spaced evenly around the perimeter. We used 18 BBR VT CONA CMI 1906 plus 204 BBR VT CONA CMI 1506 tendons. The total length of strand used was just over 211 km – making a total of 248 t of stressing steel.

IN FOCUS: Cement manufacture

Step 1: Extraction of raw materials

The raw materials needed to produce cement – calcium carbonate, silica, alumina and iron ore – are generally extracted from limestone rock, chalk, clayey schist or clay. Suitable reserves can be found in most countries.
These raw materials are extracted from the quarry by blasting. They are then crushed and transported to the plant where they are stored and homogenized.

Step 2: Raw grinding and burning

Very fine grinding produces a fine powder, known as raw meal, which is preheated and then sent to the kiln. The material is heated to 1,500°C before being suddenly and dramatically cooled by bursts of air.
This produces clinker, the basic material required for the production of all cements.

Step 3: Cement grinding and shipping

A small amount of gypsum (3-5%) is added to the clinker to regulate how the cement will set. The mixture is then very finely ground to obtain 'pure cement'. During this phase, different mineral materials, called 'cement additives', may be added alongside the gypsum. Used in varying proportions, these additives, which are of natural or industrial origin, give the cement specific properties such as reduced permeability, greater resistance to sulfates and aggressive environments, improved workability, or higher-quality finishes.
Finally, the cement is stored in silos before being shipped in bulk or in bags to the sites where it will be used.

Stressing operations were carried out with six stressing jacks which simultaneously tensioned three tendons from both ends at the same time.

A YEAR TO REMEMBER

In one year alone, BBR Polska pushed 286 km (337 t) of strand through the ducts, completed 566 stressing operations and grouted with about 160 t of cementitious grout – just for silo structures. This is quite an achievement!

TEAM & TECHNOLOGY

OWNER Kruszwica: Krajowa Spółka Cukrowa
Kujawy: Lafarge S.A.

CONTRACTOR Chemadex S.A.

DESIGNER Kruszwica: Chemadex S.A.
Kujawy: Peter und Lochner

TECHNOLOGY BBR VT CONA CMI internal

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

Local insight:
Sugar making in Poland

Poland has a great tradition of sugar making. The first sugar-beet refinery in Europe was set up in 1802 in Konary, Lower Silesia region – in fact, the sugar industry is the oldest sector of the Polish national economy. Today, with a population reaching over 38 million and sugar consumption estimated at 42 kg per capita, the country is an attractive market for sugar producers. Poland is one of Europe's largest sugar producers, ranking third after Germany and France – annual production of sugar is estimated at two million tons.

Founded in 2002, Krajowa Spółka Cukrowa S.A. (Polski Cukier S.A.) is the leading sugar producer in Poland and has a 4% share of the European market, making it the ninth largest sugar producer in Europe. The company's share of the domestic market is nearly 40% and it is one of the 'Top 100' Polish companies. The company has plants in eight districts which annually process four million tons of sugar beets, supplied by 30,000 farmers working on nearly 100,000 hectares.

KILMORE HEADWORKS UPGRADE, AUSTRALIA

"... POST-TENSIONING IS FAST, EFFICIENT, ECONOMICAL AND VERY COMPETITIVE IN THE CONSTRUCTION MARKET."

The winning tender for the design and construction of a 16 ML capacity circular water tank at Kilmore for Goulburn Valley Water, as reported by Janine Ralev of BBR Network member **Structural Systems Ltd,** was an alternative design comprising a post-tensioned precast circular tank – rather than the steel tank option documented by consultant engineers. Structural Systems' scope of works included post-tensioned structure design, documentation and structural certification, supply and installation of post-tensioning, including site supervision.

Winning alternative solution

Kilmore is a town in Victoria, Australia – 60 km north of Melbourne by the Hume Freeway and the Northern Highway. In 1841, a land speculator, William Rutledge bought an estate of 21 km^2 and named it after his birthplace – Kilmore, in County Cavan, Ireland. Kilmore is the oldest inland town in Victoria and was a convenient stop-over for many people during the Victorian gold rush of the 1850s.

PROJECT PURPOSE

There were three existing earthen basin reservoirs in Goulburn Valley Municipality in Kilmore. Reservoir 1 supplied the higher level areas and Reservoir 3 supplied the lower lying properties. Reservoir 2 was dormant.

Today, Kilmore is a growing and modern town requiring modern infrastructure.

The purpose of this project was to replace Reservoirs 1 and 3 with a covered, above ground water storage tank. This new storage tank is now located at the site of Reservoir 2.

GENERAL DESIGN ASPECTS

The tank was designed using a combination of design software fully developed in-house and commercial finite element software. The static system chosen for the Kilmore tank was a pinned base and free top of walls. The design was carried out in accordance with AS 3735 – the Australian Standard for concrete structures for retaining liquids.

The tank base slab was designed to be crack-free, have a minimum prestress after all losses in the vicinity of 1.5 MPa and special attention was paid to details of the ground and base slab preparation, in order to minimize any possible causes for the tank slab to lock during its life span.

In addition to the above, the PT slab was designed to carry loading from a mobile crane with outrigger loads of up to 70 t – while lifting the wall panels.

CASTING OPERATIONS

The floor slab was cast monolithic, with the ring beam eliminating any joints through the floor of the tank base. It was a challenge for the contractor to pour such a big slab in a Victoria country town. It took 20 hours, 45 people working from 4 am till 11.30 pm to pour 550 m^3 of concrete to complete the tank base in one pour. Initial stress was applied the next day and final stress of the ring beam and slab tendons when concrete reached 22 MPa – usually in 3-4 days.

Once the slab and the ring beam were fully stressed, casting of the panels commenced on top of the PT slab. Curved casting beds were set up in strategic locations on the slab, where up to six panels were cast at one location, then lifted and placed onto the ring beam recess progressively.

STRESSING

The tank walls were designed to withstand all the long term and short term load combinations, including water load, earthquake load, prestress load and temperature loads – and, under all combinations, the structure will still have minimum residual prestress of 0.7 MPa, as per the requirements of AS 3735.

Vertical tendons were installed in the panels and were stressed prior to the panels being lifted.

Wall hoop tendons were stressed out of stressing pilasters that were in alternating positions along the tank perimeter. One wall hoop consisted of two live-to-live tendons in round ducts. The wall pilasters were positioned at 0, 90, 180 and 360 degrees along the tank perimeter in order to minimize congestion at anchorages and maximize the stressing force in the hoop tendons.

Once all the panels were erected in place, PT strand was pushed into the PT ducts, infills poured and after required curing time of the infills, the wall hoop tendons were simultaneously stressed to a specified load. To minimize vertical bending in the tank walls, hoop tendons were stressed in two stages:

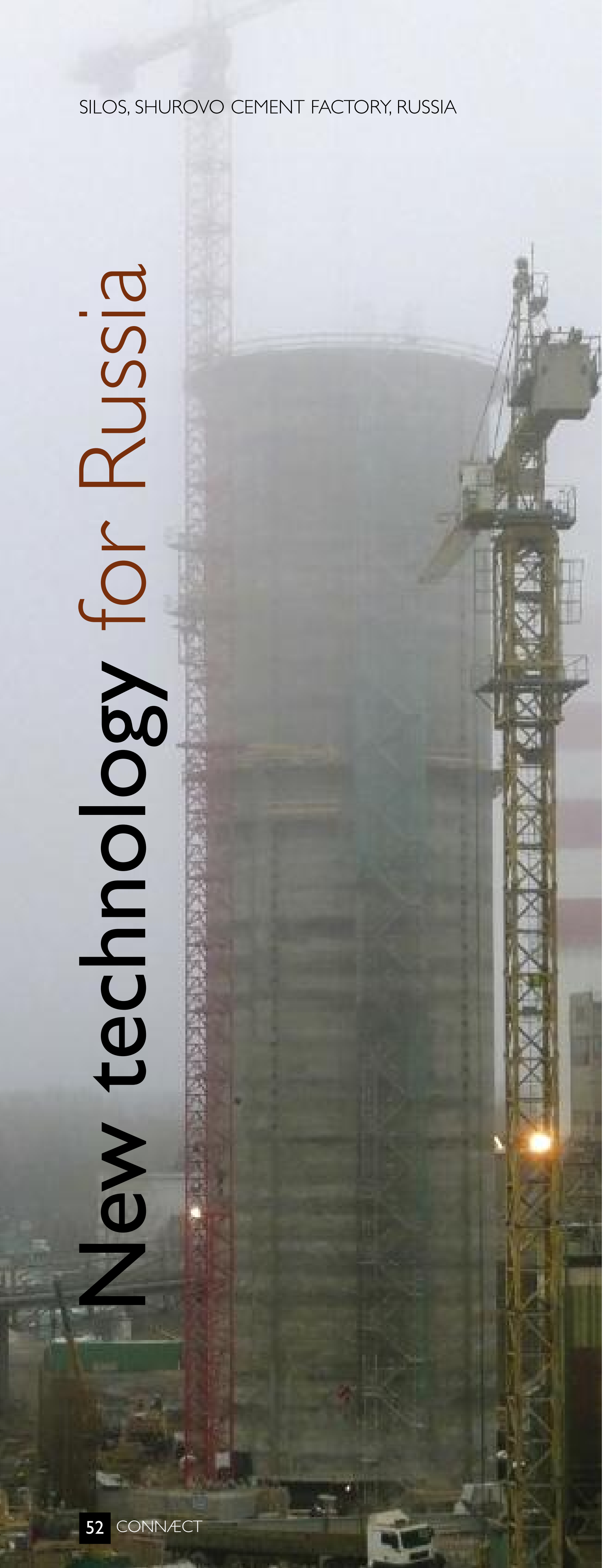
- ◆ **Stage 1** – bottom of wall free to move in the ring beam recess, 50% of hoop tendons stressed to full load.
- ◆ **Stage 2** – bottom of wall locked (pinned), i.e. grouted, the remainder of the hoop tendons stressed to full load.

The complete concrete structure was finished in less than three months which – once again – confirms that post-tensioning is fast, efficient, economical and very competitive in the construction market. ●

TEAM & TECHNOLOGY

OWNER Goulburn Valley Water
MAIN CONTRACTOR Leed Engineering Pty. Ltd
DESIGNER Janine Ralev, Structural Systems Ltd
TECHNOLOGY
BBR VT CONA CMI internal
BBR CONA flat
BBR CONA internal
BBR NETWORK MEMBER
Structural Systems Limited (Australia)

New technology for Russia



Worldwide building activities are still growing and structures made of concrete are of great importance. Accordingly, the global demand for cement has increased by 41% in the past five years. This considerable growth is noticeable in Eastern Europe – and even more in China, where the per capita consumption of cement has exceeded 800 kg according to the 'Cement Projects Focus 2010' market survey compiled by OneStone Intelligence in December 2006.

VORSPANN-TECHNIK GmbH, the BBR Network member in Germany, is currently working on a cement plant in Russia. Dipl.-Ing. Christian Leicht describes how PT work in Russia is always an opportunity and a challenge at the same time.

GOING EASTWARDS

The Shurovo Cement factory, which belongs to the Holcim Group, is located in the southeast of Moscow. The cement required to support the building boom in the Moscow region is produced here. The plant has an annual output of approximately four million tons of cement.

Some sections of the plant are out-of-date and must be reconstructed and enlarged. These are mainly the silos, the rotary furnace and the mills. In the current phase, two clinker silos and a raw meal silo are under construction. The contractor for all concrete work at the plant is Lei AG and all the post-tensioning work is being undertaken by VORSPANN-TECHNIK GmbH.

CONSTRUCTION METHOD

The 40 m diameter clinker silos were built using slipform construction techniques. This continuously moving formwork usually climbs at around 200 mm per hour. Sometimes the climbing rate for this project was less than 2 m a day – due to lack of concrete or other materials.

The start of this operation was not easy either, as many of our attempts to bring the plastic trumpets through the Russian customs were in vain. Nevertheless, the slipping of the 47 m high clinker silos has been finished successfully. The anchorages and the galvanized metal-ribbed ducts were placed during sliding, while the prestressing steel was installed afterwards, followed by stressing and grouting of the tendons.

PRESTRESSING SYSTEM

The prestressing system used for the clinker silo was BBR VT CONA CMI with 12 and 19 0.62" diameter strands with a maximum tensile strength of 1860 N/mm². The tendons make up the circumference of the silo and are stressed a third at a time to minimize friction losses. Six buttresses were formed to allow alternating tendons to be stressed at 60° to each other, ensuring loads were uniformly distributed around the silo.

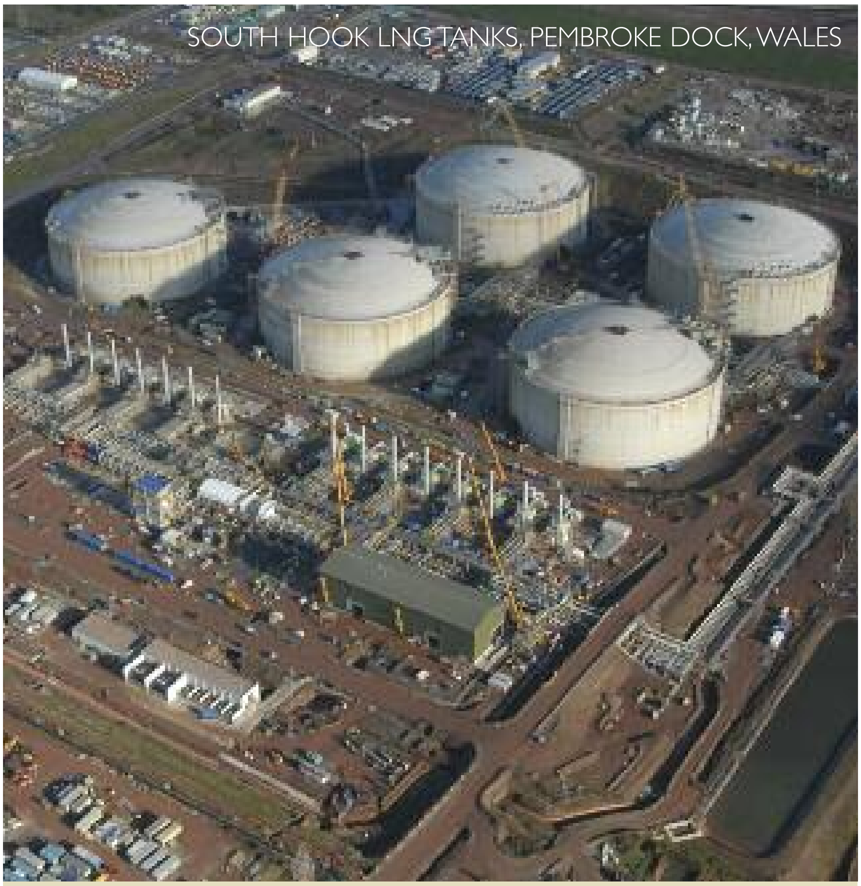
Each silo has 102 BBR VT CONA CMI 1906 tendons and 78 BBR VT CONA CMI 1206 tendons – the total amout of prestressing steel used was 165 t. After the strands had been installed with a high speed pusher from the ground, the tendons were stressed in a predetermined sequence to a load of 4,332 kN and 2,736 kN, respectively.

EMBRACING THE FUTURE

It is a privilege for VORSPANN-TECHNIK GmbH to be a member of a team which contributes to minimizing environmental pollution by building state-of-the-art facilities – especially in such an energy-intensive sector as the cement industry – and we meet the challenges which come along with such projects. Meanwhile, making improvements by bringing new technologies to other markets has always been a strong feature of VORSPANN-TECHNIK's approach.

TEAM & TECHNOLOGY

OWNER Alpha Cement Russia
MAIN CONTRACTOR Lei AG Baumanagement
DESIGNER Kottmann Engineering
TECHNOLOGY BBR VT CONA CMI internal
BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH (Germany)



SOUTH HOOK LNG TANKS, PEMBROKE DOCK, WALES

Award for LNG storage

The UK's largest civils project has been declared the winner in the civil engineering category of the 2008 Concrete Society Awards. The judges said: "The project is of the highest standard and reflects all that is best in innovative use of concrete in civil engineering".

Since we reported on this project in the 2007 edition of CONNAECT, construction of the five 92 m diameter post-tensioned LNG storage tanks in South Wales has progressed well and is now nearing completion. The team from **Structural Systems (UK) Limited** – the BBR Network member for the UK – is currently working on Tank 3 – carrying out the closure works on the temporary construction openings (TCOs), required during erection of the steel inner tank linings, internal piping and insulation material.

Strand installation began in November 2006 and since then, some 2,900 t of stressing steel has been applied to the project. With Tanks 1 and 2 already complete, three tanks will be on line shortly. Overall completion is programmed for the third Quarter of 2009.

Up, up and away!

BGC CEMENT SILO, PERTH, AUSTRALIA

Project Manager Daniel O'Leary from SSL Western had his hands full when **Structural Systems Limited (SSL)** – the BBR Network member in Australia – was contracted by BGC Cement to provide the knowledge and expertise to design and construct the slipform used in the construction of this cement silo. Structural Systems was also contracted to post-tension the silo – located in the port district of Kwinana, approximately 30 km south of Perth.

SLIPFORM PROCESS

The basic slipform process involves building a twin ring of inner and outer sets of steel shutters at ground level. As part of the slipform design, the shutter ring is braced and stiffened to maintain the cylindrical silo shape. Once all the necessary plant and materials are in place or nearby, wet concrete is poured into the shutters and the slipform rig is gradually moved upwards by hydraulic jacks fitted within the slipform structure. The 'slipping' process is then a continuous 24-hour operation until the required structure height is reached.

Some of the benefits of the slipform process are the speed of construction – 24-hour continuous operations – and the related advantage of very few construction joints, greatly reducing the risk of water ingress and potential product damage.

POST-TENSIONING

We used 200 BBR CONA internal 706 anchorages – the total weight of PT used was 17 t.

The post-tensioning process gives the silo a much greater load carrying capacity, compared to conventionally reinforced structures, and allows for very slender walls – greatly reducing materials and overall cost. The 'compressing' of the silo walls by the stressed cables means that cracking of the concrete and effects of thermal expansion induced cracking is also reduced or eliminated – helping, once again, to reduce water ingress into the structure.

TEAM & TECHNOLOGY

OWNER BGC Cement
MAIN CONTRACTOR BGC Construction
DESIGNER MPA Shedden
TECHNOLOGY BBR CONA internal
BBR NETWORK MEMBER
Structural Systems Limited (Australia)

4TH LNG TANK, CARTAGENA, SPAIN

Completion in Cartagena

Pictured here is the 4th LNG Tank in Cartagena as it nears completion. This cylindrical reinforced concrete tank made to store Liquefied Natural Gas features some 600,000 kg of BBR CONA technology which was designed and installed by **BBR PTE,** the BBR Network member in Spain. The tank has an external diameter of 78 m and is 40 m high.

TEAM & TECHNOLOGY

OWNER ENAGAS
MAIN CONTRACTOR FCC CONSTRUCCION, S.A.
DESIGNER Principia y Carlos Fernández Casado
TECHNOLOGY BBR CONA internal
BBR NETWORK MEMBER BBR PTE (Spain)

Longest in Europe

Concrete arch from axis 90 (north), construction phase 1 finished, support structure for construction phase 2 raised in place.

GRÜMPENTAL BRIDGE, GERMANY

During the summer of 2007, **VORSPANN-TECHNIK GmbH** was awarded a contract for heavy lifting work for a new railway bridge. This contract was awarded to VT because of their reputation for heavy lifting know-how. Dipl. Ing. (FH) Thomas Weber describes the work which involved repeated lifting and lowering of the shoring truss to construct the 270 m long arch – the longest concrete arch for a railway bridge in Europe. ➔

VT strands – elevator in the forward position during a lift procedure.

The Grümpental bridge is part of the new Ebensfeld-Erfurt railway route. The bridge is located near the village of Grümpen in the German State of Thuringia.
With an overall length of about 1100 m and a maximum height of about 70 m, it is one of the largest valley bridges on the route. The bridge is part of Verkehrsprojekt Deutsche Einheit Nr. 8 (German Unity Transport Project No. 8) which encompasses a 500 km length considered to be the central section of the high speed route between Munich and Berlin.

TECHNICAL DETAILS

The bridge has a regular pier spacing of 44 m along its end sections, with piers spaced every 30 m in the area over its reinforced concrete arch. It consists of three continuous beam systems with lengths of 219 m, 446 m and 439 m. The centre section (446 m) of the continuous beam is mainly supported by a concrete arch. The superstructure consists of a 3.60 m high hollow box girder, fabricated with the help of an advancing shoring. The reinforced concrete arch, also a hollow box in cross-section, has a length of 270 m and a height of almost 70 m. The arch is constructed in sections from axis 80 (south) and axis 90 (north) on auxiliary concrete piers. The shoring truss has to be lifted to the relevant construction section and subsequently lowered to the ground again after completion of the section. The arch is built in a total of nine sections, four each from the north and south and a section for gap closure at its apex.

HEAVY-LIFTING TECHNOLOGY

A total of four VT SH 1906 strand lifting jacks are used to perform the lifting and lowering of the shoring truss. Each of these jacks is fitted with 19 compacted strands – 165 mm² in cross-section area. The maximum lift / lower loads incurred at the front area of the support structure were about 200 t per jack and about 75 t in the rear area. The total lift or lower load per procedure was therefore about 550 t.

TEAM & TECHNOLOGY

CLIENT Deutsche Bahn AG

MAIN CONTRACTOR
Gerdum u. Breuer Bauunternehmen GmbH

DESIGNER Kinkel und Partner GmbH

TECHNOLOGY Heavy lifting

BBR NETWORK MEMBER
VORSPANN-TECHNIK GmbH (Germany)

Arch cross-section, VT strands – elevator in the rear position during a lift procedure.

At the apex of the arch, a maximum lift / lower height of about 55 m will be reached. The strand bundles were coiled onto special VT coiling devices for the lift procedure, from where they were uncoiled again for the subsequent lowering procedure. This made problem-free repeated use of the strand bundles possible.

LIFT PROCEDURE

During the lift procedure, all strand bundles were fastened to the shoring truss by way of pin points. At first, the truss was lifted at the front until the truss reached its final inclination for the coming arch section. Then the lifting was continued by all four strand lifters synchronously until it reached its intended position. The rear end of the support structure was then tightened onto the end of the existing arch section by way of tension bars. In the forward axis, the appropriate transversal bearing beam was pushed into a recess – prepared in the auxiliary pier – onto which the load of the shoring truss could then be transferred.

LOWERING PROCEDURE

After concrete had been cast and formwork for that section had been removed, the strand lifting equipment – consisting of jack, hydraulic pump and strandcable coiling device – were again attached to the arch and all lifting elements connected to the truss. Once the load was again transferred to the strandlifters, the rear tension bars and the transversal bearing beam were removed and the lowering procedure was performed. On the ground, the support structure was pulled on skids to the next span of the arch, in preparation for the following lift procedure.

Installation of the socket-pier.

Local insight:
German Unity Transport

Following the reunification of former East and West Germany, the government devised a program, consisting of 17 transport projects, which would provide a foundation for user-friendly and modern transport connections between the eastern and western parts of Germany. These consist of nine rail and seven motorway schemes – and even a waterway project. The € 38.8 billion infrastructure investment program was launched in 1991 to speed up the reunification process. During the 40 year separation of the German States, numerous gaps had arisen in the transportation infrastructure. By the end of 2007, more than € 27 billion of the envisaged investment – equal to around 71% of the total fund – had been used. All 17 German Unity Transport projects are now either completed or under construction.


GROUND STABILIZATION, WELLINGTON, NEW ZEALAND

Accommodating tomorrow's leaders

Located in the heart of New Zealand's capital city – well known for its hilly landscape and sometimes tortuous roads – Victoria University of Wellington doesn't have a lot of room in which to expand. Instead, it's going up, building a three-tower student accommodation complex on a small, steep and exposed site, with help from **BBR Contech** – the BBR Network member in New Zealand – and its ground-stabilization team.

The new 'Te Puni Village' will offer accommodation to over 350 students, spread over three towers that link together to provide shared administration, dining and other facilities. As the towers are sited on three descending levels of the steep site, extensive post-excavation ground stabilization and retention works were required.

The project presented a number of challenges:

- working on a confined site with restricted access for concrete trucks and other equipment
- coping with unpredictable and inclement weather
- dovetailing work with that of the building construction team
- and meeting an extremely tight deadline that required completion in time for the student intake in early 2009.

After undertaking four initial proving tests – for head contractor Hawkins Construction and engineering specialist Connell Wagner – BBR Contech and subcontract driller Richardson Drilling installed almost 400 galvanized steel 'soil nails' into the slopes, to depths ranging from four to ten meters. With the soil nails firmly grouted into the ground, the team placed reinforcing mesh across the surface and applied about 1100 m^2 of sprayed concrete to the three main walls and two pre-existing walls. They also installed 35 bored drains – running horizontally in the retained soil – to ensure efficient water drainage behind the new retaining wall.

Effective communication and co-ordination saw BBR Contech's work completed on time – enabling work to proceed on providing the University's students with modern, comfortable accommodation and spectacular views of Wellington harbor.

TEAM & TECHNOLOGY

OWNER Victoria University of Wellington
CONTRACTOR Hawkins Construction Ltd
DESIGNER Connell Wagner
TECHNOLOGY Soil nails
BBR NETWORK MEMBER
BBR Contech (New Zealand)

Extending oil production

SLEIPNER B COMPRESSION, NORTH SEA

Sleipner B is a Statoil owned platform located in the North Sea. To utilize more of the reservoirs on the oil field, a compression unit has been developed to increase the pressure in the reservoir and enable more oil to be extracted from the field. This system is used for extending the production life time of existing oil fields.

KB Spennteknikk AS was involved in the installation of the 1,300 t heavy compression unit. One of the largest offshore lifting vessels, Saipem 7000, was used for the installation to the platform. The compression unit was fixed to the platform by using 16 x 50 mm diameter stress bars, stressed to a total load of 12,000 kN. KB Spennteknikk AS supplied the specially designed bars and performed the stressing during offshore operations. The bars were protected with grease filled steel casings and end caps as corrosion protection.

TEAM & TECHNOLOGY
OWNER Statoil
CONTRACTOR Aibel AS
DESIGNER Aibel AS
TECHNOLOGY Bars
BBR NETWORK MEMBER
KB Spennteknikk AS (Norway)

Solution for **deep vertical excavation**

A 12 m deep excavation was required for a large hotel complex in the heart of India's third most populous city Bangalore – also well-known as the Silicon Valley of India. BBR Network member **BBR (India) Pvt Ltd** was commissioned to design and install passive soil anchors to tie back 600 mm diameter piles to resist lateral soil pressure without affecting nearby buildings and roads. By the end of the project, more than 800 anchors in five layers – with an average anchor length of 11 m – had been drilled, installed and grouted.

TEAM & TECHNOLOGY
CLIENT M/s. Adarsh Group
MAIN CONTRACTOR M/s. B.L. Kashyap & Sons Ltd
DESIGNER M/s. Potential Service Consultants (P) Ltd
TECHNOLOGY Soil anchors
BBR NETWORK MEMBER BBR (India) Pvt Ltd

DEEP EXCAVATION, BANGALORE, INDIA

JOHN PAUL II BRIDGE, PULAWY, POLAND

Bridge for the community

The opening and naming of the new bridge – the John Paul II Bridge – over the River Vistula in Pulawy was greeted by celebrations in the local community. No longer would they have to fold back their door mirrors to pass across the old bridge, nor would they have to endure traffic jams – one of which lasted for ten hours! Construction of the new bridge took over two years, but it was worth waiting for, reports **BBR Polska** – the BBR Network member in Poland.

The bridge is 1032.8 m long and 22 m wide – and has a 212 m steel arch main span. The BBR Polska team consisted of six people during the height of activity on site, under periodic supervision of site engineers. During the long period of construction, Tomasz Borsz and Piotr Ostrowski managed and shared the work in line with their own personal experience and the client's requirements.

Scope of BBR Polska's works

- Supply and assembly of 72 pot bearings – with capacities ranging from 1800 kN to 46,100 kN.
- Lifting of main deck section of 63.79 m length and weighing 554 t from barge to a height of 20 m.
- Lifting of external (left) arch element of about 80 m length and weighing 687 t to a height of 18 m.
- Lifting of central (joining) arch element with length of 35 m and weight of 236 t to a height of about 18 m.
- Supply, assembly and stressing of 112 hangers – ranging from 1.846 m to 22.465 m long.

ASSEMBLY OF ARCH

Two 2600 kN jacks with 12 0.6" diameter strands were used to lift the main section of the deck, installed on one side of the partially constructed bridge deck. Two 6800 kN jacks with 13 0.6" strands were installed on the other side. The jacks were connected to the BBR SL-402 system and operated from the control panel. Lifting operations, together with final joint realization, lasted three days. For lifting the external left element of arch, we used two 6800 kN jacks with seven 0.6" diameter strands, installed on the WP2 temporary tower and four BBR SL-402 1650 kN jacks with 12 0.6" strands, installed on the WP1 tower. For lifting the central element of the arch, we used four BBR SL-402 1650 kN jacks with seven 0.6" strands, installed on WP1 and WP2 temporary towers.

POT BEARINGS

Before assembly, the bearings were initially preset on site to 40 mm. Eighteen 250 t jacks were placed on sliding bearings and used for the lifting operations and changing the temporary bearings for the final ones. The lifting force needed was 1825 t for one bearing.

STRESSING HANGERS

We carried out the assembly of hangers from a barge using a movable crane. Each hanger was lifted from the barge using temporary ropes and initially connected to the upper anchorage. After suspending all the hangers, we regulated the length and joined them to the lower anchorages. The hangers have stressing couplers regulated to +/– 50 mm. BBR 40 t stressing jacks were installed on the couplers. The initial stressing force in each hanger varied from 100 up to 389 kN. After completion of the bridge deck, the final tensioning was carried out and the final stressing force in each hanger was between 430 and 580 kN.

TEAM & TECHNOLOGY

CLIENT National Highways and Motorways Authorities in Lublin (GDDKiA o/Lublin)

CONTRACTING CONSORTIUM
PRM 'Mosty Łódź SA / Herman Kirchner Polska
VISTAL Sp. z o.o.

DESIGNER PiWOM POMOST SC

TECHNOLOGY Bearings
Hangers
Heavy lifting

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

New sensing technology

BBR Network members now have direct access to the **BBR WIGAbloc** – a measuring instrument for compression forces which was recently introduced to the BBR product range.

Typical applications for BBR WIGAbloc include calibration of hydraulic jacks, stay cable monitoring, bridge load control on abutments and pylons, ground anchor monitoring, wind tower stress monitoring and many more. BBR WIGAbloc load cells come in a wide range from 5 to 20,000 kN.

When pressure is applied to the BBR WIGAbloc unit, the elastomer disc behaves like a quasifluid medium. The piezo pressure sensor – the 'heart' of the instrument – is located inside the load cell, enclosed by a solid steel structure where it is safe from external influences. This design provides some added benefits:

- Proven technology with many years of experience
- Easy mounting
- Excellent repeatability
- The cover which floats upon the elastomer adapts itself automatically to slopes of up to 3.5%
- Radial forces are transmitted from the cover to the pot wall without exerting any fundamental influence on the measurement
- Low height
- Zero maintenance

Recently, BBR WIGAbloc technology has been used in the oil industry – on NPCC's SPE350 service barge, shown here, which has a 5,000 t Clyde crane on board. The 12,000 kN sensors were fitted to the buffer section of each leg, above the moving parts. The sensor sends signals back to the main deck and jacking room, where monitoring is carried out on a 24/7 basis to ensure that early warnings are given should loading change and possibly put the barge and its crew at risk.

Making **moves**

Günter Damoser from Austrian BBR Network member **VORSPANN-TECHNIK** reports on a most unusual application for jacks and tensile elements.

CHURCH RELOCATION, RAABA, AUSTRIA

There is a traditional saying in Austria – 'Let the church remain in the village' – which actually means 'Let's not exaggerate, keep a sense of proportion'.

A couple of years ago, in the little town of Raaba, south of the city of Graz, Austria, Mr. Gangl – the Mayor – thought it would be wonderful if there were a square outside the main door of the little church. The church hosted regular services and wedding ceremonies from time-to-time, but when guests stepped out of the main doors, they found themselves on the pavement, directly beside the road.

After many investigations and planning approval, the big question remained – would the move create cracks in the building and render the building tragically useless?

A whole set of measures were taken to avoid this. The building was secured by diagonal thread bars at most of the walls. The weight of the walls and the spire was carried by additional concrete foundations and steel beams. In addition, the sliding bearings were designed to allow force / height correction during the move, through built-in hydraulic pressure elements. These were constantly observed while the church was shifted. The individual sliding bearings changed their height in a range of +/- 2 mm, while keeping the load constant. The moving force was produced by two strand lifting jacks, each furnished with four 0.6" strands. The shift was performed with an upward slope of 2%, to avoid extensive lifting before or after the move. The strand lifters could easily pull the 500 t weight over the length of 13.5 m to the building's new place.

On 16th July 2008, the church was shifted – some 100 years after it had been built in that location. Mr. Gangl, the mayor, members of the town board and very many spectators watched the moving of their church. The project was a complete success – no obvious cracks could be seen after the move, when the building including the spire had been set to its new foundation.

The social aspect of church services and wedding ceremonies can now continue comfortably outside the church in the newly-created square, where guests can stand and have a good talk or even enjoy a beverage – away from cars on the road.

And, yes – despite all these ambitious ideas – the little church did indeed remain in the village!

TEAM & TECHNOLOGY

OWNER Town of Raaba, Austria

MAIN CONTRACTOR Majcen Baugesellschaft mbH

DESIGNER Convex, Graz and Werner Unger

TECHNOLOGY Heavy lifting

BBR NETWORK MEMBER VORSPANN-TECHNIK GmbH & Co. KG (Austria)

Staying power in Valencia

SERRERÍA BRIDGE, VALENCIA, SPAIN

In the south of Valencia, the City of Arts & Sciences designed by the internationally renowned architect and engineer Santiago Calatrava has become one of the most celebrated features of the City. One of his latest designs, the new Serrería Bridge, now rises in the centre of this stunning complex to a height of 126 m – making it the highest point of the City. Representing the Serrería Bridge project team from **BBR PTE** – the BBR Network member in Spain – Diana Cobos Roger presents some construction highlights.

Serrería Bridge is a steel stay cable bridge, with a 155 m long main span. The 29 front BBR HiAm CONA strand stay cables, with 31 and 61 strands, and the four back stays with 85 strands each, support more than 1,800 t of steel used for the bridge deck. The prestressing strand is a galvanized, waxed and HDPE coextruded strand with a ultimate tensile strength of 1860 MPa and a steel cross-section of 150 mm^2.

RIGOROUSLY TESTED SYSTEM

The BBR HiAm CONA stay cable system for strand stay cable bridges has been rigorously and successfully tested for fatigue and leak tightness – with testing provisions and test results exceeding the provisions stipulated in the fib recommendation, Bulletin 30 'Acceptance of stay cable systems using prestressing steels'.

PREPARATORY WORK AND CABLE INSTALLATION

During pylon construction, three provisional front stays were installed to bear the weight of the inclined pylon. This work took place from the middle of March 2008 to the first week of May. Starting from the end of May, the installation of the BBR HiAm CONA system was performed on site using the strand-by-strand installation method, which is comprised of four basic steps:

- Installation of the upper (pylon) and lower (deck) BBR HiAm CONA anchorage.
- The preassembled compact BBR stay pipe is hung between the two anchorages using two master strands. The stay cable sheath is now

“ON 28TH JULY, WE STRESSED THE LAST STRAND – JUST TWO MONTHS AFTER THE BEGINNING THE INSTALLATION!”

used as a guide and passage from anchorage-to-anchorage.

- The strand is positioned at deck level and pulled up through the stay pipe and the upper anchorage and inserted into the lower anchorage.
- Each strand is tensioned immediately after installation, using the BBR ISOSTRESS tensioning method, ensuring an equal stress distribution among the strands of an individual cable.

BACK STAY CHALLENGE

After installing 14 stays, we then had to place the four back-stays. This process was quite a challenge for various reasons. As the duct is a steel pipe that could not be drilled, there were no ‘windows’ to work through during installation. We placed the top anchor heads on an auxiliary structure and then brought them into position, with the 85 strands (weighing 15 t each) hanging from them. At the lower end, it was a similar situation, with us lifting the anchor heads into position.

PROTECTION AND MAINTENANCE

Another challenge for us was ensuring that the steel duct and the strands worked as one single structure while, at the same time, preserving the option of removing one strand for maintenance or replacement should it become necessary. The back stays have been very challenging in terms of aerodynamics and BBR headquarters in Switzerland developed and analyzed a special configuration, where the whole 116 m long almost vertical back stay pipe was injected with special grout to add extra mass, which enhances the overall aerodynamic behavior and each strand was protected with an individual HDPE tube (outside diameter 25 mm) which allows the replacement of any strand individually if required. In addition, all four back stays were fitted with external helical ribs and advanced BBR Square Dampers to provide supplemental damping to the cables. This configuration not only provides an enhanced aerodynamic performance and allows replacement of individual strands, but also provides enhanced fire resistance of the four back stays which hold the entire pylon in position.

STRESSING OPERATIONS

The stressing of the back stays had to be carried out simultaneously for all four stays, so we used four multi-strand jacks situated on the top of the pylon.

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Technical insight:
BBR Square Damper

Despite the wide use of cable-stayed bridges, there are still several areas of great concern, particularly the effects and elimination of cable vibration phenomena such as vortex shedding, galloping, parametric excitation and wind and rain induced vibration.

Various countermeasures are available – for example, the use of helical rib on the cable surface or cross-ties.

Supplemental damping devices add damping to the cable – hence achieving sufficient total damping as an efficient measure against cable vibrations.

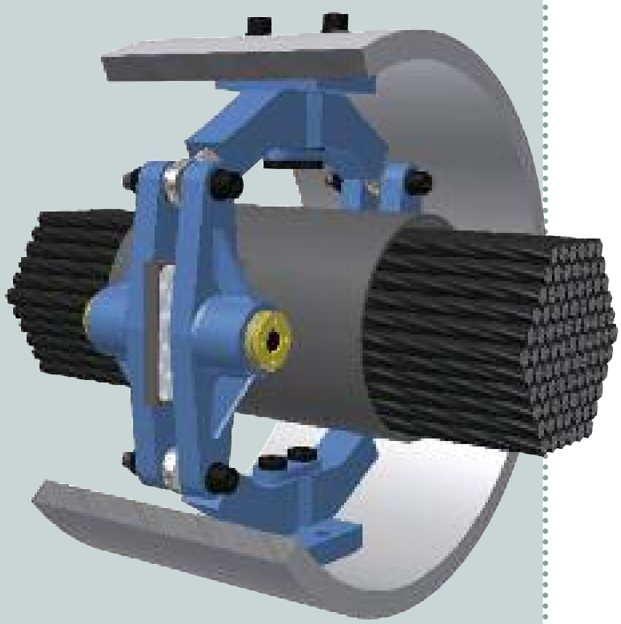
An advanced cable damping solution is the BBR Square Damper. The BBR Square Damper is based on friction and is essentially an adaptation of the braking system of an automobile. The device can be used as an internal damper, where it is installed inside the steel guide pipe or alternatively as an external damper, attached to the free cable length using a damper housing and external brace. The basic characteristics of the BBR Square Damper are:

- The damper is not activated at low and non-critical cable vibration amplitudes, to avoid constant working of the damper and therefore minimize maintenance requirements.
- The damping efficiency is independent of the acceleration and mode of cable vibration.
- Free longitudinal movement of the stay cable at the damper location is provided (allowing temperature elongation and force variations of the stay cable without constraints).
- The damping characteristics can be adjusted at any time by changing the ‘clamping’ force.

Its simple design, high efficiency, easy adjustability and low maintenance requirements make the BBR Square Damper a superior damping device when compared to other products, such as oil dampers.

The BBR Square Damper can effectively damp stay cables over a wide range of possible amplitudes of cable vibration. The device can be fine-tuned and adjusted during its entire service life to best suit a particular cable configuration and specific susceptibilities to particular vibrations.

All components of the damper can inspected individually and are replaceable if required (due to external damage, vandalism etc).



Then we continued the stressing operations with front stays 15 to 29, using the same system for strand-by-strand installation – even for the longest stays which were 250 m long. On 28th July, we stressed the last strand – just two months after beginning the installation!

ENHANCED BBR DAMPING

Besides compact BBR stay pipes with helical ribs, we installed internal BBR Square Dampers on the stays at deck level. Subsequently, all stays were tested and they all complied with the theoretically stipulated values. On 20th August 2008, load testing of the bridge was carried out – with great results and the bridge was finally opened to traffic on 22nd August 2008 – in time for the Formula 1 Grand Prix weekend in Valencia!
Once again, an amazingly high performance was attained during installation, making the aspiration of opening this ambitious project to traffic in the last week of August a reality.

TEAM & TECHNOLOGY

OWNER Ciudad de las Artes y las Ciencias S.A.
MAIN CONTRACTOR
JV FCC Construccion + Pavasal
DESIGNER Santiago Calatrava Architects & Engineers
FCC Technical Services
TECHNOLOGY
BBR HiAm CONA
BBR Square Damper
BBR NETWORK MEMBER
BBR PTE (Spain)

In Focus: Valencia's son

It is particularly fitting that the world-famous architect and engineer Santiago Calatrava should produce the Serrería Bridge and many other beautiful new structures in this location – as Valencia is the city of his birth.
During his early years, Calatrava must surely have been enthralled by the vast array of architecture in the city – ranging from the ancient winding streets of the Barrio del Carmen with ancient Roman and Arabic buildings, to the Estación del Norte built in the early 20th century.
Calatrava studied at the Arts & Crafts School and then as an undergraduate at the Architecture School in Valencia. After graduating in 1975, he pursued a civil engineering degree at the Swiss Federal Institute of Technology in Zurich. In 1981, he set up his practice in Zurich and since then – operating from a network of offices in many countries – he has created a vast number of award-winning and awe-inspiring structures around the globe.

Santiago Calatrava – architect and engineer (photograph copyright: Suzanne DeChillo / The New York Times)

INSTALLATION OF LOCKED COIL ROPE STAYS, CÓRDOBA & ZARAGOZA, SPAIN

Uniquely engineered

The installation of locked coil ropes in a structure is a delicate process. David Olivares of Spanish BBR Network member, **BBR PTE,** explains that due to the great variety of sockets and the particular nature of each structure, every such project needs to be treated individually.

We have recently completed two such projects – the Palma del Río Bridge in Córdoba and a pedestrian cable stayed bridge for Expo'08 in Zaragoza.

PALMA DEL RIO BRIDGE

The new bridge over the Guadalquivir River in Palma del Rio is a suspended deck arch bridge with a span of 130 m. The two arch planes are inclined from the vertical with 46 hangers on each side. Inside of this plane the hangers are inclined too. These hangers consist of a locked coil rope that supports the composite deck. The cables have diameters of 37 and 45 mm and have a pin open socket in both ends.

We carried out the installation and stressing of the hangers. The main operations performed are described below.

The upper socket was lifted and pinned by means of a crane. Then, in the lower socket, a special connecting steel piece was fixed by a pin. This connecting piece allows the cable to be bolted to a deck plate.

To stress the hangers, hydraulic bolt tensioners were applied. In the connecting plates, there were six holes for the permanent bolts, the two centre holes were used to stress two temporary bolts, using the tensioners.

We used a 23-step stressing sequence where, for each step, two pairs of stay cables were simultaneously stressed. For that reason, a total of eight tensioners were utilized at the same time. Two high pressure hydraulic pumps with a capacity of up to 1,500 bar were connected to the tensioners.

TEAM & TECHNOLOGY (Palma Del Rio)
OWNER Junta De Andalucia
MAIN CONTRACTOR FCC Construccion
DESIGNER IDEAM + FCC Technical Services
TECHNOLOGY Stay cables
BBR NETWORK MEMBER BBR PTE (Spain)

EXPO'08

At the end of April 2008, the 'Pasarela del Voluntariado' was inaugurated for the international EXPO'08 which was held in Zaragoza. In just ten months, the footbridge had been completed.

The 235 m long curved steel deck is supported by 47 stay cables which are anchored to a tilted central steel pylon.

The locked coil ropes are classified as five different types according to their cross-section dimensions – 31, 35, 40, 45 and 128 mm diameter. In this case, the upper end is a pin open socket and the lower end is a threaded socket with a spherical nut.

The installation of the cables was completed in three stages, each of them with several sub-phases. At the start, the deck was supported by six temporary towers and the central pylon anchored to the foundation system. The first stage was the lifting of the cables and the next two stages consisted of two consecutive stressing operations. The cables on the left and right side of the pylon were installed and stressed alternately to keep the balance of the structure.

To stress the cables, post-tensioning strands were anchored to the lower end. The cylindrical socket has an external and internal thread. The external one is for the permanent nut and the internal one is designed for stressing only during erection. Threaded post-tensioning anchor heads – 4 x 0.6", 7 x 0.6" and 19 x 0.6" – were threaded for stressing. A multistrand hydraulic jack with a special shuttle stressed the strands to the required stressing force.

TEAM & TECHNOLOGY (Expo '08, Zaragoza)
OWNER Ayuntamiento De Zaragoza
MAIN CONTRACTOR FCC Construccion
DESIGNER Carlos Fernandez Casado
TECHNOLOGY Stay cables
BBR NETWORK MEMBER BBR PTE (Spain)

DUNAJEC RIVER BRIDGE, BREZNA, POLAND

Complex **challenge**

The building process, technology and materials used during bridge construction over the Dunajec River in Brezna near Stary Sacz delivered a world class solution to a complex challenge. On behalf of **BBR Polska,** Marcin Ornat managed the technology and prestressing, while Tomasz Borsz was in charge of suspension operations – together, they take up the story.

The bridge was designed as a continuous three span beam structure, with pylons placed on the intermediate supports. The 300.76 m long bridge has three spans – 77.92 m + 143 m + 77.92 m. Diagonal stay cables, supporting the spans, are anchored at the top of the pylons which stand 18.47 m high above the deck. The bridge has two arrays of stay cables, laid out in a fan shape. Six pairs of stay cables emerge from the head of each pylon.

In cross-section, the girder is of the single box type and it has a height of 3.4 m along the whole length of the structure. The beam consists of two concrete decks (upper and lower) connected by two steel pipe trusses. The width of the deck is 14.11 m. Over each support there are concrete cross-beams constructed in the superstructure. Steel pylons were installed on the external parts of the intermediate support cross-beams. The bridge was executed by the incremental launching method. The bridge over Dunajec River is the first stay cable construction in Poland, where webs made from steel pipe trusses were used in the concrete construction of the main girder. The complexity of the construction and scope of various works connected with technology and prestressing made BBR Polska the obvious choice and optimal partner for the joint venture of strong local bridge contractors ZRM Mostmar SJ and MOSTY Chrzanów Sp. z o.o.
BBR Polska's work was undertaken in three phases:

Scope of works

BBR Polska's contract included supply of materials, specialist equipment and the following works:

- delivery and prestressing of steel bars which anchored the launching nose to the bridge construction
- delivery of materials, equipment and execution of 13 phases of bridge launching
- delivery of materials and execution of prestressing (construction stage longitudinal tendons, deck transversal prestressing unbonded tendons, transversal bonded cables at stays connections, external continuity tendons)
- delivery and installation of pot bearings
- execution of prestressing bars fixing lower stays anchorages
- delivery of materials and execution of bridge suspension with BBR CONA stay cables
- delivery and installation of expansion joints

- Phase 1 – incremental launching and prestressing necessary during the launching process.
- Phase 2 – prestressing of stays fixation elements and continuity prestressing.
- Phase 3 – bridge structure suspension.

Today, the bridge over Dunajec River in Brezna has blended beautifully into the landscape of this mountain valley. As well as an extended transport system for Stary and Nowy Sacz, the region has also acquired a new and interesting structure. From our side, the experience gained from working on this relatively small but technically complex structure will be of great value on future projects.

TEAM & TECHNOLOGY

OWNER
Management of Voivodship Roads, Krakow, Poland

MAIN CONTRACTOR Joint venture of ZRM Mostmar SJ and MOSTY Chrzanów Sp. z o.o.

DESIGNER Piotr Wanecki (bridge structure)

TECHNOLOGY Launching
BBR VT CONA CMI internal
BBR VT CONA CME external
BBR VT CONA CMM unbonded
BBR CONA stay
Bearings and expansion joints

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

FORT HATRY RAILWAY BRIDGE, BELFORT, FRANCE

Overnight installation

This pedestrian bridge over a railway line was preassembled and welded near one of the abutments and erected by a crane in just one night, using the prefabricated cables, supplied and installed by French BBR Network member **ETIC.**

After erection of the deck, the cables situated behind the pylon were connected to special foundation blocks, while the cables in front of the pylon were anchored by means of tie bolts placed between two anchor plates – one was fixed on the back the pylon head, the other through an axis on the deck.

After the first phase of cable tensioning, the slab – made of prefabricated plates of concrete attached to the steel beam – was installed. A second phase of tensioning was performed after the road deck was finished.

TEAM & TECHNOLOGY

OWNER City of Belfort

MAIN CONTRACTOR JV Richert-Gagne

DESIGNER Arcadis, Cabinet Tonello

TECHNOLOGY BBR DINA stay

BBR NETWORK MEMBER
ETIC S.A. (France)

STAY CABLES

CABLE STAY BRIDGE, AUCKLAND, NEW ZEALAND

Collaboration for NZ first

A nationwide design competition has led to the construction of New Zealand's first-ever cable-stayed road bridge – a landmark structure that is providing a distinctive gateway to the new Flat Bush township in Manukau City. Paul Wymer and Hugo Jackson of **BBR Contech** – the New Zealand-based BBR Network member – report on the result of extensive collaboration between their company and the Swiss-based BBR headquarters, as well as the pioneering achievement which continues the BBR Network's global success with cable-stayed structures.

Manukau City's Flat Bush township is New Zealand's newest urban development, designed to provide a high-quality living environment for up to 40,000 people by 2020.

The entrance to the town centre is dominated by the Ormiston Road bridge – an awe-inspiring sight that lifts the road above a 100-year flood plain. At 70 m long and 27 m wide, the box girder structure features four traffic lanes, two cycle ways and footpaths on both sides, with a 3.5 m wide void down its centre to allow natural light beneath.

But of course its most dramatic features are the 46 m high pylons from which the bridge is suspended – and the 20 cables supporting it, supplied and installed by BBR Contech.

TOUCHING THE GROUND LIGHTLY

Cable-stay bridges are a rare sight in New Zealand – indeed, the Ormiston Road bridge is the only such traffic bridge in the country, reflecting the designer's vision of a structure that 'touches the ground lightly'.

However, despite its apparently simple structure, the bridge construction was technically complex owing to its asymmetric geometry and the very tight tolerances specified.

The bridge's pylons taper from 1.8 m in diameter at the base to 1.3 m at the top, with a 5.5 m high structural steel box providing anchorage for the stay cables, topped with a 12 m lattice spire of stainless steel and glass.

To further complicate the situation, the non-self-supported pylons incline longitudinally at 15 degrees and together at 5 degrees, meaning there was very little tolerance in ensuring the stay cable aligned correctly between the pylons and the deck anchorages. The positional tolerance of the top stay anchorages had to be within 3 mm – at 33 m above ground level!

PARTNERSHIP FOR PROGRESS

This requirement for meticulous accuracy governed the project, imposing stringent attention to risk management and construction detail.

"RECOGNIZING THE ADVANTAGES OF COLLABORATION, BBR CONTECH CALLED ON THE EXPERTISE AND EXPERIENCE OF THE BBR HEADQUARTERS ..."

Recognizing the advantages of collaboration, BBR Contech called on the expertise and experience of the BBR headquarters. The international team worked with main contractor Fulton Hogan Civil and principal design consultant Beca Infrastructure to deliver the result Manukau City was looking for.

The 20 cable stays supporting the bridge deck – with lengths of between 20 and 53 m – are configured using the BBR DINA stay cable system. The largest tendon comprises 144 7 mm high tensile wire elements with a maximum UTS approaching 10,000 kN. Each of the wires is individually galvanized, housed within a specially manufactured polyethylene sheath which is filled with a proprietary corrosion inhibitor. These tendons connect to the pylons via large cast-steel clevises, which when installed weigh close to a ton each.

Almost 70 km of wire had to be measured and cut, then installed complete with clevises using two cranes and a mechanical excavator. Cable tensioning had to be started during installation and before the cranes were released – and pylon movement closely monitored throughout.

It was a difficult, but highly satisfying project – and the results are well worth the effort. The Ormiston Road bridge is an iconic entrance and exit point that is a real tribute to the teamwork and international collaboration behind it.

TEAM & TECHNOLOGY

OWNER Manukau City Council

MAIN CONTRACTOR Fulton Hogan Ltd

DESIGNER Beca Infrastructure Ltd

TECHNOLOGY BBR DINA stay

BBR NETWORK MEMBER
BBR Contech (New Zealand)

Technical insight:
Wind induced drag force on stay cables

Wind induces static and dynamic effects on cable stays and should therefore be taken into account during design. The static drag force of wind on a stay cable causes significant horizontal stresses on the pylon, particularly on large cable-stayed bridges.

The drag force F_d is given by:

$F_d = ½\ \rho\ U^2\ D\ C_D$

Where ρ is the density of air (1.23 kg/m^3), U is the wind velocity, C_D is the drag coefficient and D is the outer cable diameter.

As the formula above indicates, the predominant factor is wind velocity as it goes in square. For instance, the drag force increases by 78% when U rises from 30 m/s to 40 m/s – assuming the other factors remain stable.

In a classic case of circular stay pipes, the value of the drag coefficient depends on the wind velocity, or more specifically on the Reynolds number R_e, and the roughness of the outer casing. Cable stays are commonly in the supercritical range in strong winds. A C_D of 0.5 for a smooth BBR stay pipe and a drag coefficient of 0.55-0.60 for a BBR stay pipe with helical rib can be achieved in wind tunnel tests. Nevertheless, the effects of extreme winds are often calculated by adopting a C_D of 0.70-0.80 to be on the safe side and to allow for the possible evolution of surface roughness (dirty etc.) over time.

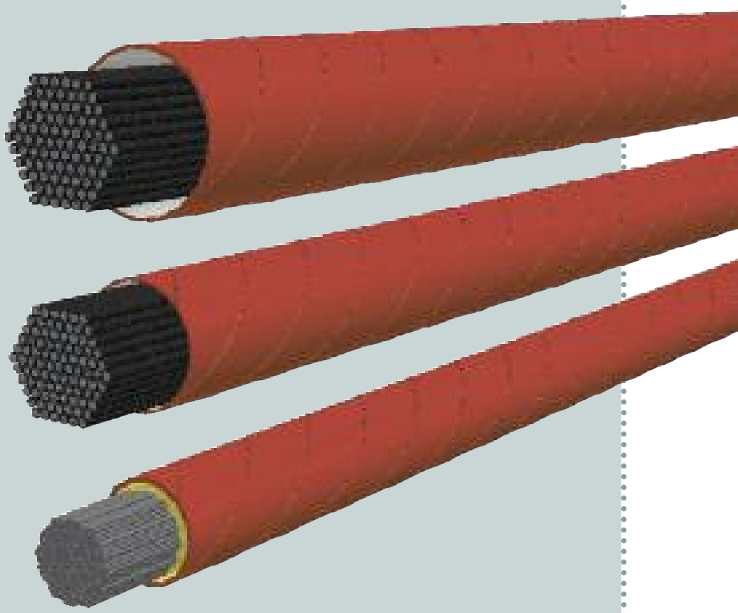
Reduced wind loads can be achieved by reducing the outer cable diameter. For long span bridges, where the cable stay drag is a preponderant factor, the installation of compact BBR stay pipes can be evaluated. The compact system enables the drag force to be reduced by 20% compared to the standard system. This system requires special material and installation techniques on site. BBR's first application of compact stay pipes was in 2000, when the 475 m long Rama VIII Bridge in Bangkok, Thailand was erected.

In comparison with BBR strand stay cable technology, BBR DINA/HiAm wire stay cables enable even smaller pipe diameters – a reduction of up to 35% relative to the standard strand system. BBR DINA/HiAm cables are composed of individual seven millimeter wires that are anchored by means of buttonheads. BBR wire stay cables have been used for nearly 50 years. They can be completely prefabricated or assembled on site before they are installed and stressed. BBR wire cables were for instance applied on Tatara Bridge, Japan, the longest bridge in its class in the 20th century and on New Zealand's first stay cable structure Ormiston Road Bridge.

BBR HiAm CONA standard strand stay pipe

BBR HiAm CONA compact strand stay pipe

BBR DINA/HiAm wire stay pipe



Solution of choice

RIO SECO BRIDGE, CASTELLÓN, SPAIN

Following on from the environmentally friendly Green Bridge in Australia, completely dedicated to public transport, cyclists and pedestrians, BBR Stay Cable technology is again the solution of choice for another public transport project – this time being provided by the local BBR Network member – **BBR PTE** – in Spain. The new guided bus / tramway in Castellón crosses the Rio Seco on a cable stayed bridge supported by BBR HiAm CONA stay cables.

This new bridge forms part of the tramway system which connects the west of the city of Castellón, where the university is located, with the coast.

The stay cable bridge has a Y-shaped steel pylon with five front and five retaining stays, on both sides of the Y, holding a 105 m length deck. The most striking design feature of this bridge is the 55 degree tilt angle of the slab axis with the abutments, giving rise to a huge variety of stay sizes – ranging from 30 up to 109 strands and lengths from 35 to 100 m.

Longitudinal post-tensioning of the slab was performed using BBR VT CONA CMI 3106 tendons, transverse PT consists of 1506 tendons. The retaining part of the slab is connected to the ground by 42 x 75 mm diameter post-tensioned bars.

The installation of the stays began in the second week of January 2008, working on both arms of the Y-shaped pylon. The installation of the 20 stay pipes and more than 1,500 strands (threading and stressing) was finished in less than three weeks. The final stressing tuning (limited to two stays) and the rest of the works, such as the wax injection of the anchor heads, the installation of the centralizers and the anti-vandalism tubes demanded two more weeks. Finally, load testing was carried out on 19th February.

The most significant benefit reaped by the owner of any BBR HiAm CONA cable stayed structure – in addition to its high fatigue resistance and the facility to replace any part of a stay if required – is its suitability for any construction process, enabling a very high level of adaptability and performance during the installation of the stays.

TEAM & TECHNOLOGY

OWNER Conselleria d'Infraestructures i Transport de la Generalitat Valenciana

MAIN CONTRACTOR
FCC CONSTRUCCION + LUBASA

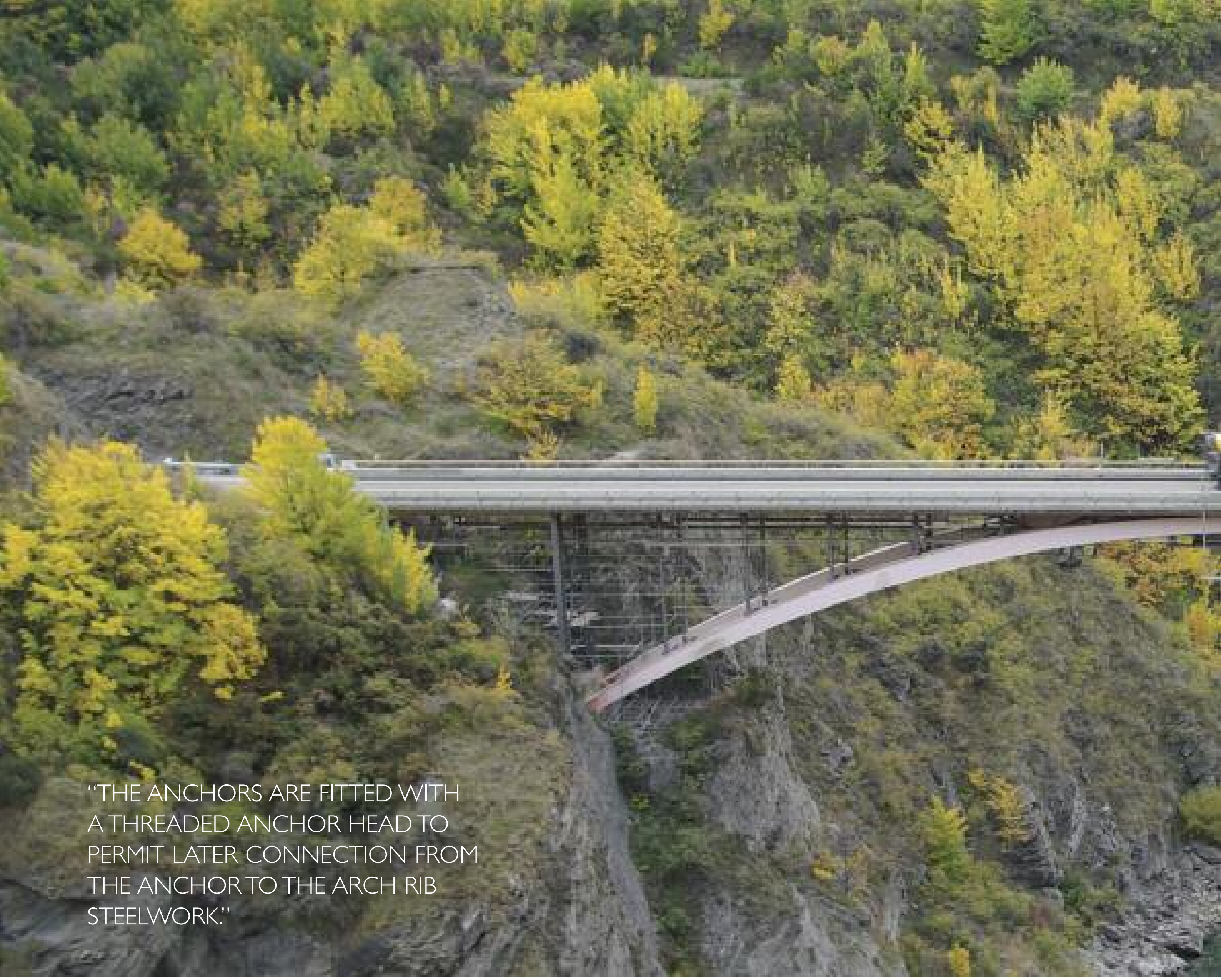
DESIGNER IDOM, Madrid

TECHNOLOGY
BBR VT CONA CMI internal
BBR HiAm CONA
Bars

BBR NETWORK MEMBER
BBR PTE (Spain)

moving with the times

Soon after the first permanent settlers arrived in New Zealand in 1840, they began building the country's roads, railways and bridges. Many of the bridges continue to be used today – but some, like that spanning the South Island's Kawarau River, have had to be replaced. However, as Peter Higgins and Paul Blundell of **BBR Contech** – the BBR Network member in New Zealand – found out while working on the new bridge, this does not necessarily mean that the old one is no longer being used! ➔



"THE ANCHORS ARE FITTED WITH A THREADED ANCHOR HEAD TO PERMIT LATER CONNECTION FROM THE ANCHOR TO THE ARCH RIB STEELWORK."

It's not often that a BBR Contech bridge project takes place in clear sight of another one, but during the recent refurbishment work on the newer Kawarau River bridge, the team had company – just 100 m away. That's because the original 1880-built suspension bridge is now home to AJ Hackett Bungy Queenstown – the original (and world's first) 43-metre jump to which tens of thousands of people flock every year.

It made for an interesting experience for us – an occasional audience as we worked beneath the old bridge's 1963 replacement, while remaining unseen by the vehicles traveling overhead.

VITAL STRATEGIC LINK

Located just a short drive out of Queenstown – known as the adventure capital of New Zealand and a major tourist destination – the new Kawarau River bridge is a distinctive landmark with its sweeping steel arch and the expansive river beneath. It's also a vital strategic link for Central Otago traffic – most notably for people traveling the South Island tourist route between Queenstown and Christchurch.

ENSURING SEISMIC RESILIENCE

In 2008, the New Zealand Transport Agency awarded the contract to strengthen the bridge as part of its national seismic retrofitting program to upgrade bridges to current seismic standards. BBR Contech's work – undertaken in conjunction with main contractor Fulton Hogan and infrastructure specialist Opus International Consultants – consisted of providing lateral and longitudinal restraint to the bridge by installing anchors into the surrounding rock at the arch ends and special cable linkages at the abutments and central arch pin connection.

"It was a challenging project, especially given the height above the river at which people had to work," said Fulton Hogan's Contract Manager Mike Wardill. "In addition, the bridge's design meant we experienced up to four or five inches of rolling movement underneath as the traffic load on the bridge transferred to the arches. This, combined with working from scaffold at great height above a raging river, meant we sometimes had a more exhilarating ride than the bungy jumpers!"

DRILLING & TENSIONING

During the two-month project, holes were drilled through the existing anchor block either side of each arch rib and eight BBR CONA 1005 permanent rock anchors – ranging in length

"THE BBRV BUTTON HEAD WIRE CONFIGURATION IS IDEALLY SUITED TO SHORT, HIGH CAPACITY TENDONS."

from 18-28 m – were installed and accurately positioned to match the angles of the arch ribs. The anchors are fitted with a threaded anchor head to permit later connection from the anchor to the arch rib steelwork.

The anchors were then tensioned before structural steel specialists welded steel brackets to the arch ribs. BBR Contech then connected the anchors to the new steel sections, using a specially designed BBRV cable stay linkage tendon, each with a capacity of 2,730 kN. The BBRV button head wire configuration is ideally suited to short, high capacity tendons. Similar cable link tendons were also installed at the central arch pin joint to provide additional seismic restraint at the mid-span location.

"Having worked with BBR Contech before, we knew they would deliver on this project," said Mike Wardill. "They are highly organized and always professional, with a strong technical background supported by practical knowledge. They are all you could ever want on a project such as this."

TEAM & TECHNOLOGY

OWNER New Zealand Transport Agency
MAIN CONTRACTOR Fulton Hogan Ltd
DESIGNER Opus International Consultants
TECHNOLOGY
BBR CONA rock anchors
BBRV wire
BBR NETWORK MEMBER
BBR Contech (New Zealand)

WESTFIELD LONDON DEVELOPMENT, UK

Elegant **retrofit solution**

The Westfield London development – an iconic retail and leisure complex in London's Shepherds Bush – has been the focus of major strengthening works using CFRP composites. Robin Kalfat, Senior Design Engineer of **Structural Systems UK Ltd** – the BBR Network member in the UK – reports that CFRP is a cost-effective technology suited to wide application in the strengthening of post-tensioned slabs.

This massive development on the former White City site comprises retail, commercial, cinemas and public buildings with a total nett lettable area of approximately 120,000 m^2. We have post-tensioned two suspended slabs for the car park and retail area.

Strengthening of the slabs was necessary due to change in ownership and tenants who required design changes – including the introduction of 15 large escalator, stair and lift shaft penetrations. Each penetration, typically 1900 by 4200 mm in size, was required through three to four levels in any particular location.

The strengthening was required as a result of the loss of pre-stressed strand and reinforcement – as well as the additional loadings and stresses induced in the slab by the redistribution of moments and forces in the vicinity of the penetration.

GENERAL DESIGN ASPECTS

The design of externally bonded FRP reinforcement for flexural members relied on composite action between the pre-stressed concrete element and the fibers which are bonded to the surface of the concrete using epoxy resin. The design procedure is analogous to that of traditional reinforced concrete, with the difference being in the initial strains present in the concrete at the time of application of the FRP.

The design procedure consisted of a verification of both the stresses and strains in materials – concrete, steel reinforcement and prestressed strand – at both service and ultimate limit states. The strains in these materials were checked against limiting values set out in the current design standards.

Design of the FRP was carried out in accordance with the Concrete Society's Technical Report No. 55 (2000). The most critical aspects of design were:

- an assessment of capacity of the existing structure
- determination of the required capacity of the slab
- limiting stresses and strains in the material
- checking the mechanisms of de-bond and anchorage design.

INSTALLATION & CONSTRUCTION

Prior to application of the CFRP, the surface was prepared by removing the cement laitance and all

"THE CFRP APPROACH ELIMINATED ANY PROBLEMS WITH ACCESS AND SERVICES THAT A MORE BULKY STRUCTURAL STEEL STRENGTHENING SOLUTION WOULD HAVE CAUSED"

surface contaminants. This was achieved by wet open grit blasting – selected to minimize the effects of dust on other trades within the zone. This left an open substrate with exposed fine aggregate and an average surface roughness of around 0.5 – 1.0 mm. All areas were thoroughly water jetted afterwards to remove resultant debris adhering to the surfaces, and allowed to dry for 48 hours prior to any further works being carried out. Pull off tests were subsequently carried out to verify the tensile strength of the substrate exceeded the minimum requirement of 2.0 MPa.
The plates with epoxy applied were raised to the concrete substrate and pushed in place using light pressure from the fist, then with a hard rubber roller in a manner which causes the adhesive to be expelled at both edges of the laminate. This guaranteed the expulsion of voids and a thorough application of adhesive and this was carried out with an overall average adhesive thickness of 2 mm.

KEY BENEFITS

CFRP is extremely light weight considering its superior tensile strength properties and has an overall plate thickness of as low as 1.2 mm. The CFRP approach eliminated any problems with access and services that a more bulky structural steel strengthening solution would have caused and lent itself to cost-effective strengthening while achieving aesthetically pleasing results.

SPEED OF CONSTRUCTION

We completed all remediation works within the House of Fraser store in a 12-week period, enabling the developer, Westfield, to meet their deadline and secure a timely handover to tenants. This was accomplished by innovation in construction sequencing and propping staging which allowed multiple installation crews working simultaneously to complete the strengthening of all eight penetrations in this zone by the required deadline.

TEAM & TECHNOLOGY
OWNER Westfield London
MAIN CONTRACTOR
P.C. Harrington (Contractors) Ltd
DESIGNER Structural Systems (UK) Ltd
TECHNOLOGY MRR range
BBR NETWORK MEMBER
Structural Systems (UK) Ltd

SEISMIC STRENGTHENING, CHRISTCHURCH, NEW ZEALAND

MRR

Preserving the past for the future

BBR Contech, the BBR Network member in New Zealand has carried out seismic strengthening at one of the city's most significant heritage sites. Peter Higgins reports on their work within the Christchurch Arts Centre complex.

The team took full advantage of FRP's qualities for restoration projects – lightweight, thin material and easy to apply, yet offering an impressive strength-to-weight ratio. It is also corrosion resistant and can be covered with a variety of plaster finishes and coatings – ideal when trying to achieve a close-to-original finish. In all, some 200 m^2 of FRP fabric was applied before the internal linings were reinstated to return rooms to near-original condition – with no visible sign of the restoration work beneath.
The former Arts School building is the second of 18 in the Arts Centre which have been targeted for seismic strengthening – part of the Arts Centre of Christchurch Trust's plan to ensure the buildings last for future generations.

TEAM & TECHNOLOGY
OWNER Christchurch City Council
MAIN CONTRACTOR
Fletcher Construction
DESIGNER Holmes Consulting Ltd
TECHNOLOGY MRR range
BBR NETWORK MEMBER
BBR Contech (New Zealand)

System in transit

ITTS BEARING REPLACEMENT, GATWICK AIRPORT, UK

Jeff Booth, Specialist Construction Manager of **Structural Systems (UK)** Ltd, the BBR Network member in the UK, reports that the team is currently working on a major project at BAA's London's Gatwick Airport to accommodate the replacement of the Inter Terminal Transit System (ITTS) – an automated driverless train system.

Although all the transit sub-systems and station refurbishment will take place during a complete seven month shutdown of the system starting in September 2009, the bridge bearing replacement work is being carried out in advance of the main works.

In conjunction with our bearing supplier, we undertook a full survey to confirm bearing condition, numbers and types. It became apparent that there were issues with the existing bearings that would affect the installation of the new ones. We were able to provide BAA with a solution for the replacement of the 628 bearings supporting the 1.2 km dual track system – whilst keeping the ITTS operational.

THE SOLUTION

This solution involves welding new supports to the existing bearing dowels, providing new fixity for the new bearings. Last summer, a full scale mock up was set up in our workshop in West London and sample welds were sent off for testing and certification, as part of this trial.

We also produced temporary works designs in-house for the provision of restraints to the structure while the bridge is being jacked to allow the replacement of the bearings. Jacking will be achieved with the use of a recently purchased 12 point synchronized lifting unit – with its operating tolerances of +/- 0.25 mm, we will be able to control the jacking and de-jacking process very accurately .

QUALITY MATTERS

All design and temporary works designs have been undertaken by SSL UK and independently checked and verified by us, in accordance with BAA's design process requirements. The delivery and recording of quality – both in the manufacturing works and on site – are equally important and the BAA Project Quality Leader has worked closely with our team in developing installation activity check sheets and quality record sheets to satisfy all parties' requirements, so that final assurance can be agreed.

TEAM & TECHNOLOGY

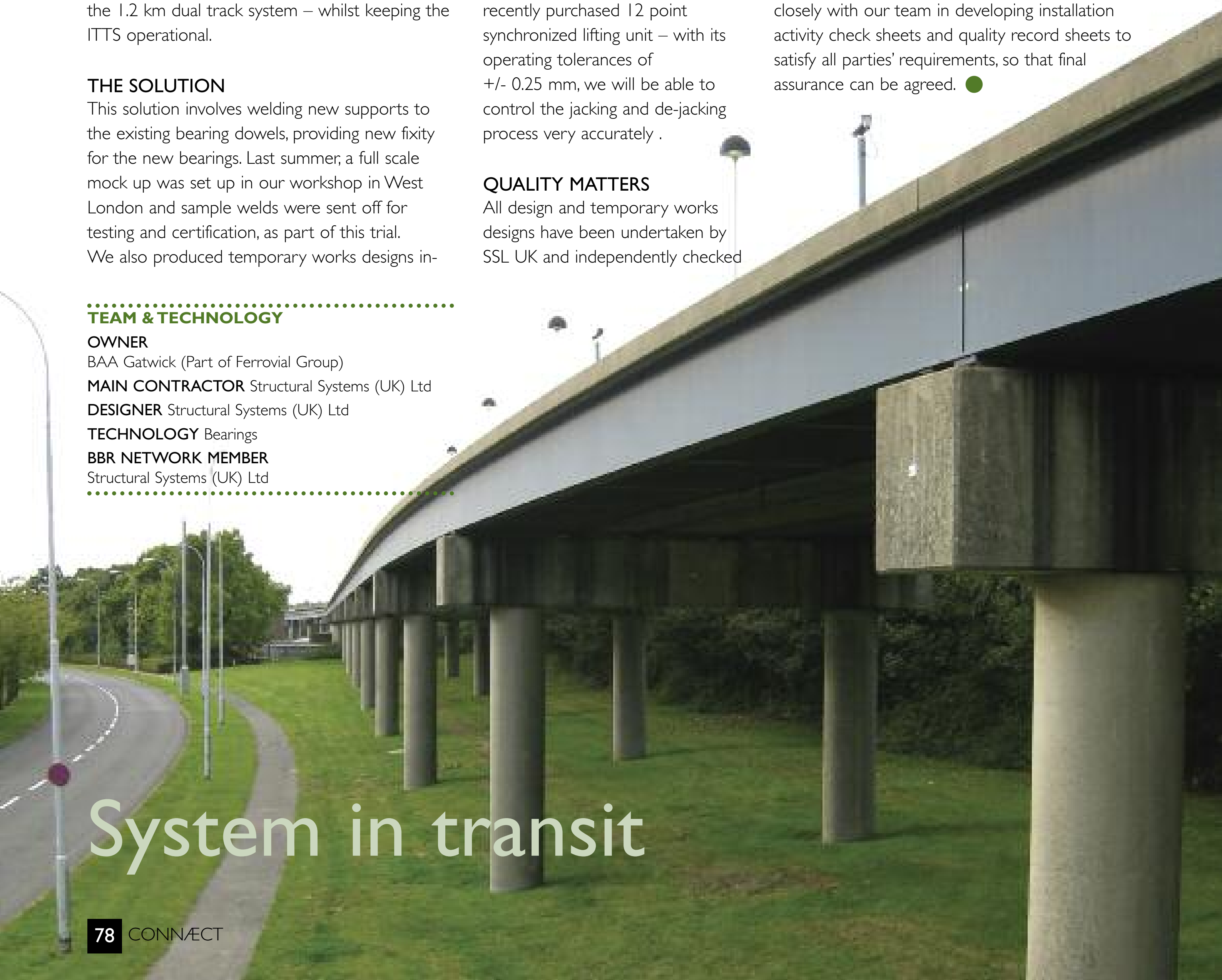
OWNER
BAA Gatwick (Part of Ferrovial Group)

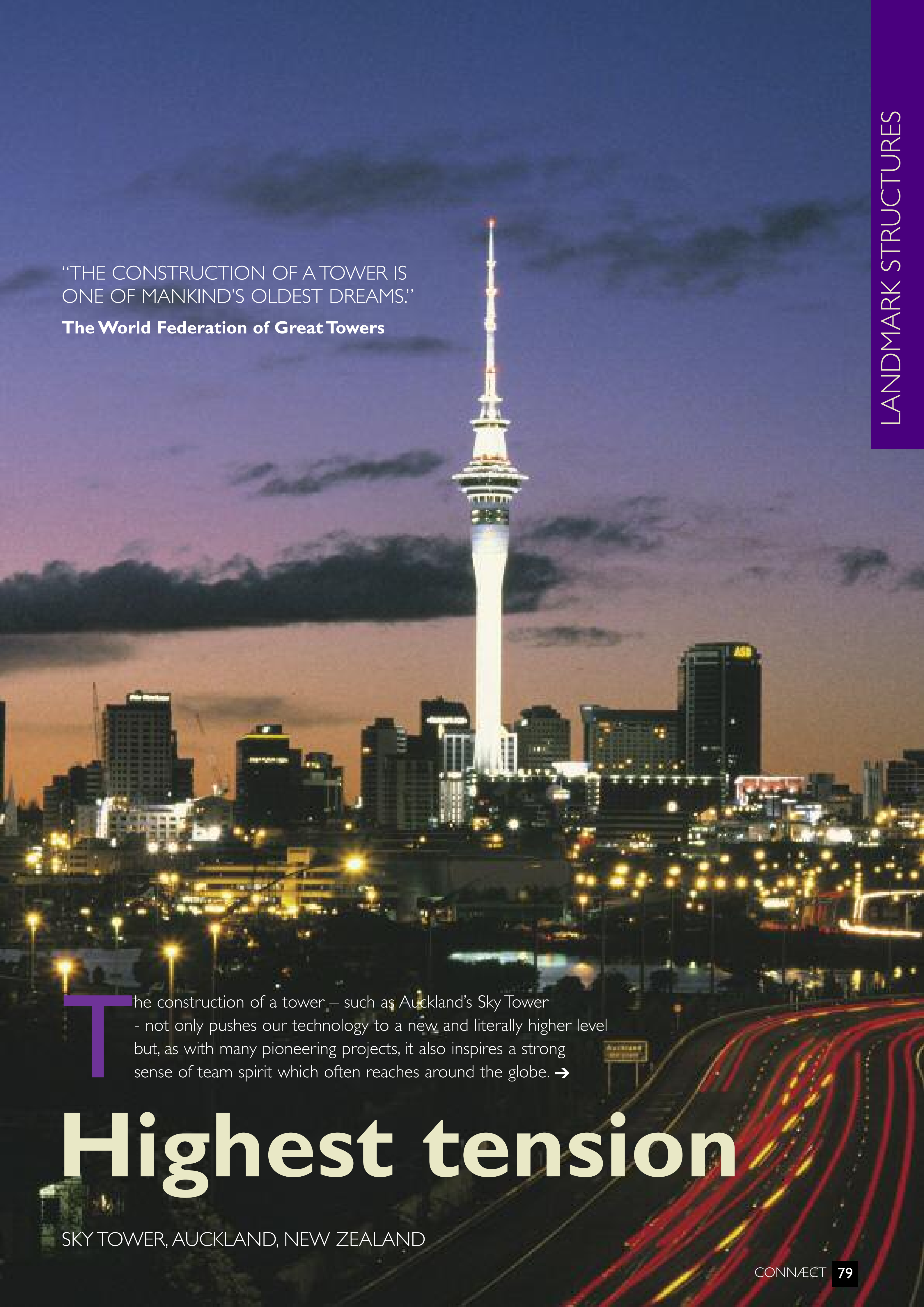
MAIN CONTRACTOR Structural Systems (UK) Ltd

DESIGNER Structural Systems (UK) Ltd

TECHNOLOGY Bearings

BBR NETWORK MEMBER
Structural Systems (UK) Ltd





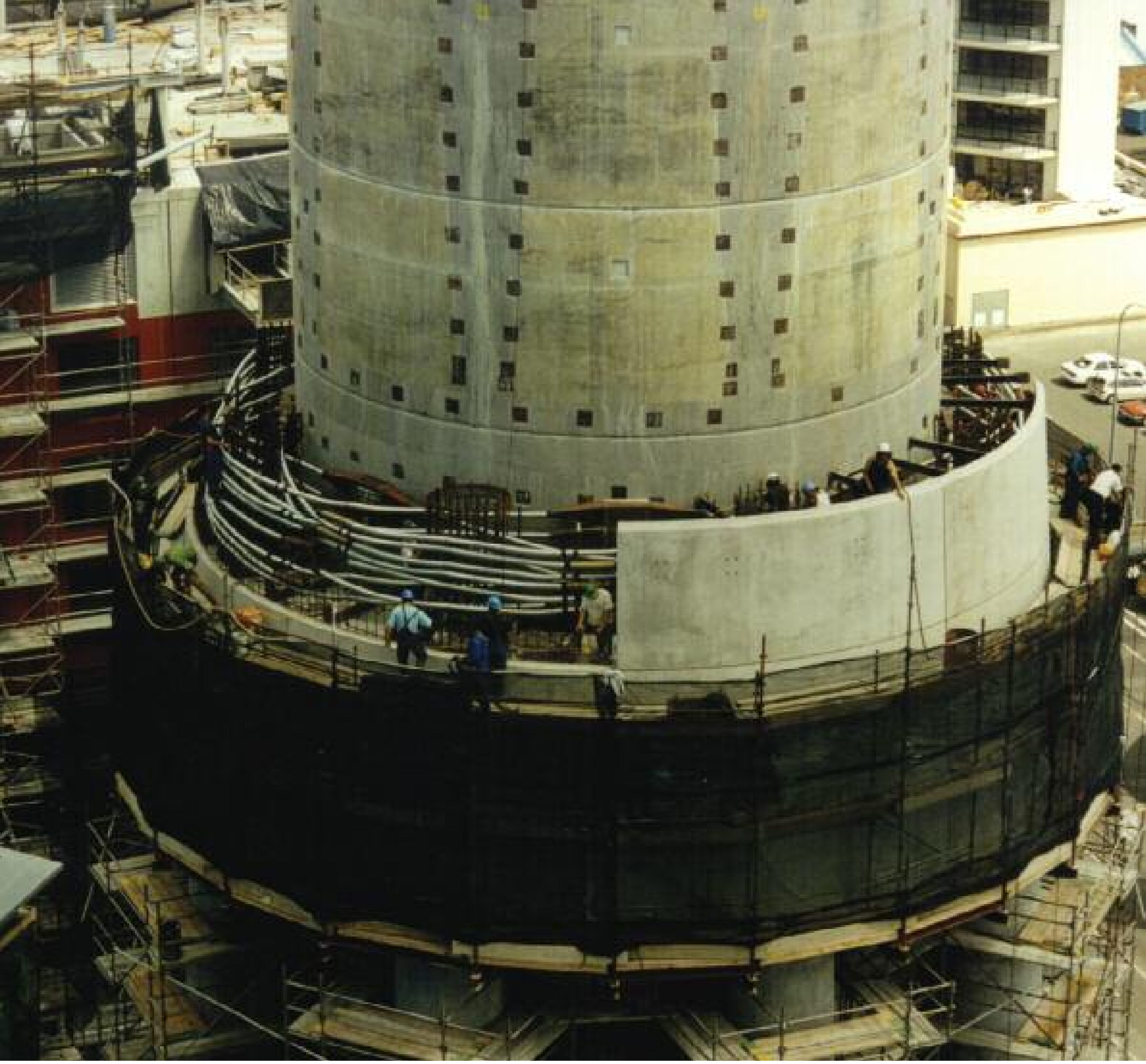
“THE CONSTRUCTION OF A TOWER IS ONE OF MANKIND’S OLDEST DREAMS.”

The World Federation of Great Towers

The construction of a tower – such as Auckland’s Sky Tower - not only pushes our technology to a new and literally higher level but, as with many pioneering projects, it also inspires a strong sense of team spirit which often reaches around the globe. ➔

Highest tension

SKY TOWER, AUCKLAND, NEW ZEALAND



Robert Robinson of **BBR Contech** – the BBR Network member in New Zealand contracted to install the Sky Tower in late 1995 – recalls the unique technological challenges which brought this landmark structure to Auckland's skyline and community.

Opened six months ahead of schedule in March 1997, at 328 m Sky Tower is the tallest tower in the Southern Hemisphere and is the 12th tallest tower in the world – overtaking the Eiffel Tower in Paris by four meters. As well as being an icon for Auckland, the tower serves as a telecommunications hub.

The tower forms part of Sky City – New Zealand's largest casino – and the facility also includes two hotels, a convention centre, a 700-seat theatre and 12 restaurants and bars.

CONSTRUCTION OVERVIEW

Sky Tower was constructed from a high strength, high performance concrete.

The main structure of the tower is a 12 m diameter reinforced concrete shaft. This is supported by eight reinforced concrete 'legs' at the base, which are connected to the shaft by a concrete collar and designed to spread force load. The upper floors of Sky Tower have been constructed using composite materials, structural steel, pre-cast concrete and reinforced concrete. The exterior of the pod levels is finished in an aluminum cladding with blue-green reflective glass.

Above Sky Deck, a structural steel framework rises to support the upper lift machine room and a concrete ring slab which supports the mast. A multi-section structural steel framework rises above the top of the shaft. Constructed of steel tubes, the mast is bolted in sections and provides space for the antennas and other communications equip-ment. The mast is equipped with specially designed tuned dampers to limit its vibration in the wind.

Telecommunications facilities, above and below the centre pod, are housed on silver aluminum-clad communications floors. Emergency stairs and service utilities are located within the centre of the shaft.

PLACING THE TOWER

In the weeks leading up to Christmas 1995, the Auckland Sky Tower's weight was quietly transferred from the base of its shaft to its eight inclined legs, in a unique operation carried out by BBR Contech.

Normally, in building a high tower, you would start with a wide base and taper it inward as the construction goes upwards. Not so at Sky Tower. Consulting engineer Beca Carter Holdings & Ferner and contractor Fletcher Construction New Zealand and South Pacific decided to adopt a unique method of construction whereby the legs were built independently of the shaft and were subsequently locked to the shaft by means of a large circumferentially post-tensioned collar located at the top of the legs.

Conceptually, the idea was simple and had advantages such as speed of construction, but the various stages posed a number of practical problems. Firstly, how much force was needed to 'clamp' the collar onto the shaft? Opinions varied and debates ensued – eventually 32 rings of circumferential post-tensioning tendons were used providing a clamping force of ultimate total strength 73,600 kN. Subsequently, BBR Contech was awarded the contract to develop the special system of post-tensioning required for the project. With the assistance of BBR headquarters in Zurich, BBR Contech developed a centre stressed prestressing tendon which was capable of being stressed from its mid-point – instead of its ends, as is normal practice. The type of tendon provided considerable advantages because it meant that the stressing pockets required to house the anchorages were located on the inside of the shaft walls and not the exterior of the collar, where architects Craig Craig Moller insisted the visible surface be factory-made fair-faced precast concrete panels.

To transfer the weight of the tower from its shaft base to the eight inclined legs meant that it was necessary to 'lift' the tower off its base and 'sit' it on the legs. This was achieved by locating eight jacks, of 700 kN capacity each, at the top of each leg and then jacking the shaft upwards, so that the load was transferred from the shaft base to the legs.

POST-TENSIONING THE COLLAR TO THE SHAFT

The post tensioning required by the designers consisted of 32 complete rings of tendons each 2300 kN UTS to be tensioned through recess pockets 360 mm high x 75 m wide and over 500 mm deep through the shaft wall. This gave a total of 73,600 kN UTS of potential clamping force. Each complete ring tendon had two stressing anchorages located diametrically opposite each other.

"THIS WAS THE FIRST TIME A BBR CENTRE STRESSING ANCHORAGE OF THIS SIZE HAD BEEN USED ANYWHERE IN THE WORLD."

LARGEST STRESSING ANCHORAGE

To satisfy the demanding requirements of the designers, BBR Contech offered the BBR Multiwire Z36 internal anchorage, developed specifically for this project. This anchorage features the well-known button-headed wire concept which has been in use worldwide for more than 37 years. To facilitate installation, non-stressed couplings were located midway between the stressing anchorages. Previously, this centre stressing anchorage had only been available in up to 1000 kN capacity, for use in flat slab post-tensioning where access to the perimeter of the slab was not available for tensioning. This was the first time a BBR centre stressing anchorage of this size had been used anywhere in the world. Tendon materials comprising special grade low relaxation 7 mm wire were imported from Germany. The high tensile steel plate manufactured specially for the Z36 anchorage was imported from Australia. The two 2000 kN capacity stressing rams were also designed and built in Auckland, during the extremely tight six week procurement period permitted by the contract.

TESTING TIMES

A test program was undertaken to prove that the anchorage components were capable of withstanding, without deformation, 110% of the ultimate capacity of the tendon. This testing was carried out in Contech's 6000 kN compression frame located at their component production factory in Masterton, New Zealand. Subsequent testing of the entire system, including anchorages, tendons, stressing jacks, gauges, pumps and handling equipment was carried out in Contech's East Tamaki, Auckland facility using a large concrete test beam specifically constructed for the purpose. →

Perfectly perpendicular

During construction, constant verification, using the most sophisticated telemetry ever employed in New Zealand, was necessary to ensure Sky Tower was perfectly straight. This telemetry encompassed three key techniques.

The first is called resection where measurements were taken from three different existing points surrounding Sky Tower – in this case the ASB Bank building, Mount Eden and the Coopers and Lybrand building – to derive the precise centre point of the structure.

Secondly, during construction of the shaft, lasers positioned on the base pad of Sky Tower shone up to the jump form platform in a grid pattern to provide verticality readings.

Finally, daily real-time readings were taken of the structure using seven global positioning satellites. These satellites confirmed the exact position of Sky Tower.

Sky Tower Facts & Figures .....

Fabrication of the BBR Multiwire tendons also took place at the East Tamaki factory. Each complete ring comprised two separate tendons which were joined at their mid-point using a threaded coupling. The tendons were transported to site on flat bed trucks and craned into position, placed on previously installed tendon supports.
The concrete collar was cast in three lifts, with the previous section being stressed to the collar before the subsequent section was cast.

TENSIONING OPERATION

The tensioning operation involved inserting the specially designed 200 kN rams through the shaft wall into the centre of the stressing anchor recess boxes. Stressing the tendon ring was carried out simultaneously from opposite stressing anchorages. The anchoring load achieved was 1700 kN per tendon. Friction in the tightly curved corrugated steel ducts was as low as $\mu = 0.14$ and $k = 0.0007$/m. The application of the 55,000 kN force used to clamp the ring to the tower shaft took eight working days.
On completion of all tensioning, the anchor recesses were concreted and the tendons grouted using a high shear colloidal mixer and multi-stage mono pump, which due to the confined space inside the shaft, had to be located at ground level.

TOWER'S WEIGHT TRANSFER TO LEGS

Eight 7000 kN capacity flat jacks (total 56,000 kN) were air freighted from Europe and tested for water tightness under stringent QA procedures at Industrial Research's laboratory in Gracefield. An ammonia leak test was used, with each jack being tested to 1.25 design working load using the laboratory's 300,000 kN test rig.
The jacks were installed, in a pocket on top of the leg, to a placing tolerance of 2.5 mm. The hydraulic plumbing was via high pressure lines which passed through the shaft wall.
On completion of the collar tensioning – and at a time when wind speeds of less than 36 km/h could be expected for several days – the eight flat jacks were inflated using water as a hydraulic fluid. They were maintained under design load for more than 24 hours. This allowed the concrete legs to shorten under the load of the tower, while still ensuring the transfer of the designed weight of the structure to the legs. The large upwards force exerted on the collar increased the separation between the legs and collar by 5 mm, resulting from a combination of compression of the legs and tilting of the tower shaft. The movement very closely matched the design figure of 6 mm. The gap between the top of the leg and the underside of the collar was then filled with high strength proprietary grout to retain the load and lock the system in place.
Following curing of the grout, the load in the eight jacks was released and the starter rods – which were cast into the legs and protruded into the collar inside corrugated ducting – were grout filled. Finally, the flat jacks were reinflated to 1400 kN each with low exotherm epoxy resin replacing the water.
The conceptual design and carrying out the transference of the weight of the Sky Tower to its legs was a considerable challenge for both the designer and BBR Contech over the 18 month period of the work. The detailing and planning, by all concerned, which went into this aspect of Sky Tower's construction ensured the ultimate success of this precise and difficult operation.

Beacon for the community

A prominent feature of Auckland's skyline at night, Sky Tower is illuminated in a variety of ways to show support for various causes. Recent examples include:

BLUE – Auckland Rugby

PINK – Breast Cancer Awareness

RED & GREEN – Kidz First Children's Hospital

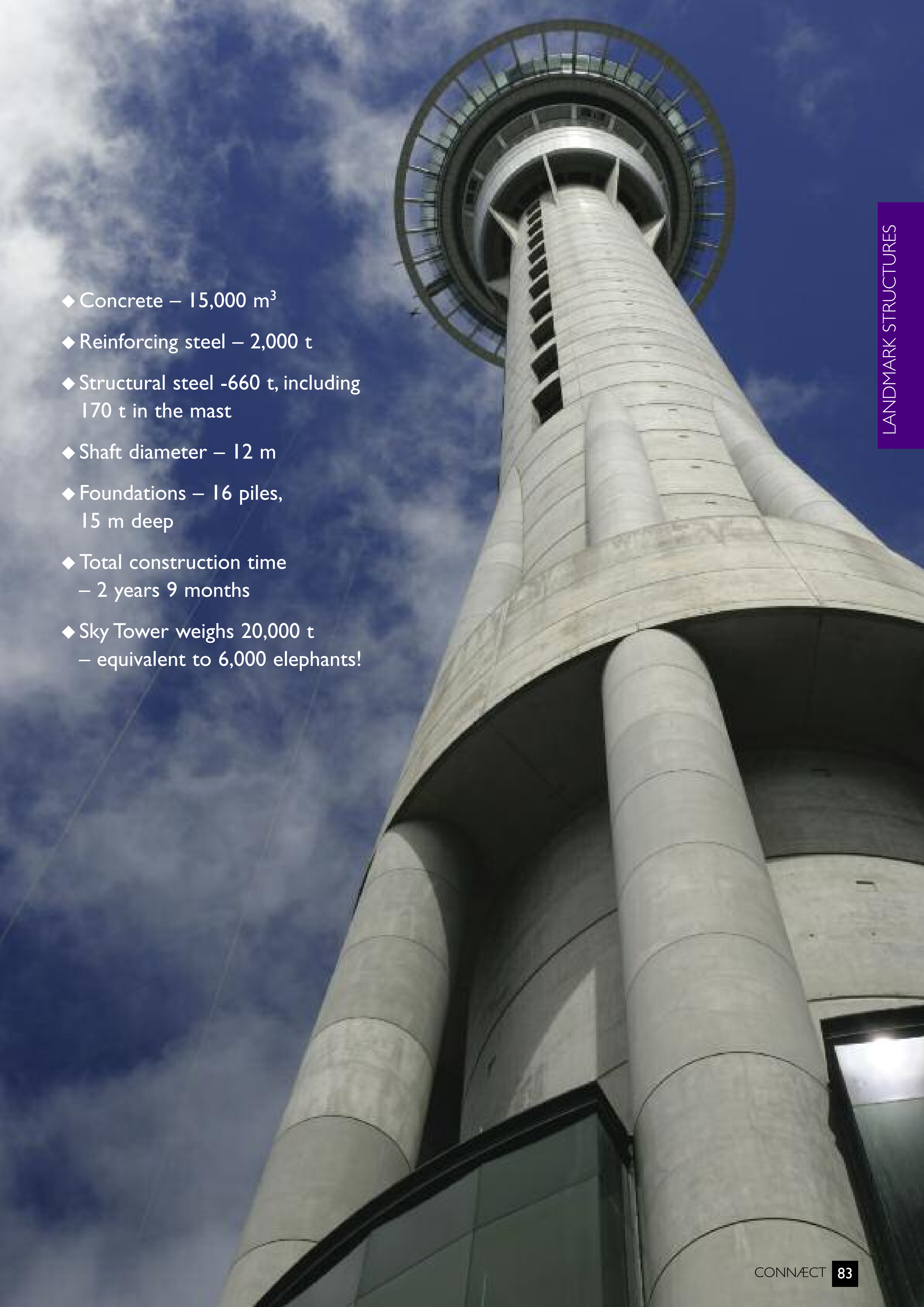
BLUE & GREEN – Starship Children's Foundation

ORANGE – Auckland Festival

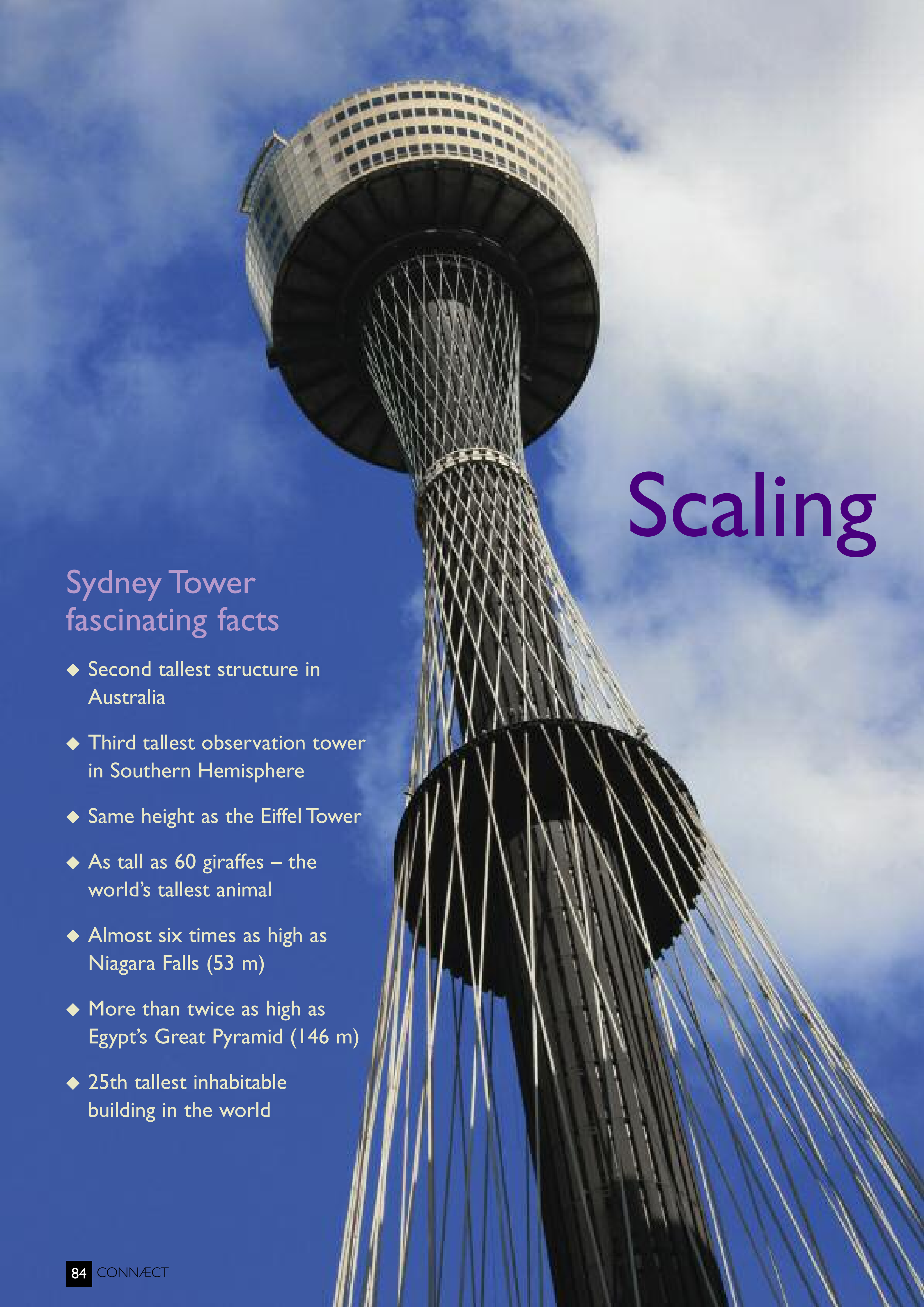
GREEN & PURPLE – The Auckland Cup

RED – The America's Cup

GOLD – supporting New Zealand athletes during the Beijing Olympics



- Concrete – 15,000 m^3
- Reinforcing steel – 2,000 t
- Structural steel -660 t, including 170 t in the mast
- Shaft diameter – 12 m
- Foundations – 16 piles, 15 m deep
- Total construction time – 2 years 9 months
- Sky Tower weighs 20,000 t – equivalent to 6,000 elephants!



Scaling

Sydney Tower fascinating facts

- Second tallest structure in Australia
- Third tallest observation tower in Southern Hemisphere
- Same height as the Eiffel Tower
- As tall as 60 giraffes – the world's tallest animal
- Almost six times as high as Niagara Falls (53 m)
- More than twice as high as Egypt's Great Pyramid (146 m)
- 25th tallest inhabitable building in the world

SYDNEY TOWER, AUSTRALIA

Almost 30 years after it was opened, Robert Freedman of BBR Network member **Structural Systems** reflects on the construction and enduring qualities of the Sydney Tower – which now stands together with the Sydney Opera House and the legendary Sydney Harbour Bridge as one of the famous city center landmarks.

new heights

Originally constructed as the defining architectural feature of the Centrepoint retail and commercial development, the tower is now Sydney's tallest structure. The 309 m high tower was opened in August 1981 as a communications tower and tourist facility. Like it's neighbor across the Tasman Sea in Auckland, the Sydney Tower is a focal point for all who live in or visit the city

RAISING THE SKYLINE

When it opened in September 1981, Sydney Tower was the fourth tallest building in the world. Before the tower was built, the maximum allowable height of a Sydney building was 279 m to allow for the harbour's flying boats that were popular before the modern jet era.

The maximum allowable height was lifted to 305 m with the approval of Sydney Tower. Sydney Tower still sets the height limit for Sydney buildings today.

CONSTRUCTION PROFILE

The cost of building Sydney Tower was A$ 36 million – one third the cost of the Sydney Opera House – a huge amount at the time.

Construction of the Centrepoint Tower – now officially known as the Sydney Tower – began in 1975. Its unique supporting net structure, composed of BBR DINA stay cables, sets it apart from the crowd.

This project involved the erection of a steel tower which rose 230 m above the roof of the 12-level office building in the centre of Sydney, Australia. Its shaft is stayed by a system of BBR parallel-wire prestressing cables. The tower is topped by a turret of five levels accommodating two revolving restaurants and two observation decks.

The steel shaft is 6.75 m overall diameter and consists of 28 columns spaced equally around its perimeter.

STAY CABLES

The 56 stay cables are formed into a hyperboloid of revolution – in mathematics, a hyperboloid is a quadric, a type of surface in three dimensions – in two groups, each of 28 straight cables. The cables are anchored to the roof of the building in a circle of 37.2 m diameter. From here, the BBR cables – each made up of 235 galvanized wires of 7 mm diameter – rise through an intermediate coupling point at 90 m, tangentially to a neck connector on the shaft 140 m above the roof. The cables, which lead from here to the turret anchorage at 184 m, each comprise 55 wires of 7 mm diameter. In plan, the cables appear similar to spokes of a huge bicycle wheel – this arrangement assists in resisting torsional moments on the tower.

The cables were manufactured in Structural Systems' Melbourne factory and transported to site on timber drums for uncoiling and installation. Stressing was carried out in two stages at night to reduce the transversing effects of the sun on the cables during daylight hours.

The weathered effect on the structure is caused by special alloying elements which react with the air to form a dense tight oxide film to protect the steel from corrosion. The appearance, texture and maturity of the weathered steel's patina depends upon three primary natural factors – time, the degree of exposure and atmospheric environment. With time, the oxide coating changes from a rusty red-orange to a dark purple-brown.

Since it opened, Sydney Tower has welcomed more than 17 million visitors – or four times the population of Sydney!

THE ULTIMATE FITNESS CHALLENGE!

One of the city's annual highlights is The Sydney Tower Run-Up – a staggering 1504-step endurance race up the stairs of the Sydney's highest building – Sydney Tower. All ages and types of people take part in this now well-established event in the Sydney calendar

The 2008 Tower Run-Up, held in support of The Heart Foundation, marked the 16th time that the event had been held – and 290 competitors lined up to take the challenge. The winner completed the challenge in just seven minutes 49 seconds. Both he and the fastest female runner have won the opportunity to take their step-scaling skills to the US with the major prize of return airfares to New York to take part in the annual race up the stairs of the 86-storey Empire State Building in 2009.

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