

CONNECT

THE MAGAZINE OF THE GLOBAL BBR NETWORK OF EXPERTS

Edition 10 | 2016

DURABILITY AS A DELIVERABLE

BBR technology & expertise
delivers durable infrastructure

ELECTRICALLY ISOLATED PT TENDONS

Launch of new BBR technology

GATEWAY TO SOUTH EASTERN EUROPE

New passenger terminal at Zagreb Airport

OPTIMIZED BRIDGE CONSTRUCTION

New guidelines encourage innovation in Norway

VOYAGE OF DISCOVERY

Excellence in BBR stay cable technology
for Poland's Rzeszów Bridge



BBR A Global Network of Experts

www.bbrnetwork.com

The BBR Network is recognized as the leading group of specialized engineering contractors in the field of post-tensioning, stay cable and related construction engineering. The innovation and technical excellence, brought together in 1944 by its three Swiss founders – Antonio Brandestini, Max Birkenmaier and Mirko Robin Ros – continues, more than 70 years later, in that same ethos and enterprising style.

From its Technical Headquarters and Business Development Centre in Switzerland, the BBR Network reaches out around the globe and has at its disposal some of the most talented engineers and technicians, as well as the very latest internationally approved technology.

THE GLOBAL BBR NETWORK

Within the Global BBR Network, established traditions and strong local roots are combined with the latest thinking and leading edge technology. BBR grants each local BBR Network Member access to the latest technical knowledge and resources – and facilitates the exchange of information on a broad scale and within international partnering alliances. Such global alliances and co-operations create local competitive advantages in dealing with, for example, efficient tendering, availability of specialists and specialized equipment or transfer of technical know-how.

ACTIVITIES OF THE NETWORK

All BBR Network Members are well-respected within their local business communities and have built strong connections in their respective regions. They are all structured differently to suit the local market and offer a variety of construction services, in addition to the traditional core business of post-tensioning.

BBR TECHNOLOGIES & BRANDS

BBR technologies have been applied to a vast array of different structures – such as bridges, buildings, cryogenic LNG tanks, dams, marine structures, nuclear power stations, retaining walls, tanks, silos, towers, tunnels, wastewater treatment plants, water reservoirs and wind farms. The BBR™ brands and trademarks – CONA®, BBRV®, HiAm®, HiEx, DINA®, SWIF®, BBR E-Trace and CONNÆCT® – are recognized worldwide.

The BBR Network has a track record of excellence and innovative approaches – with thousands of structures built using BBR technologies. While BBR's history goes back over 70 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 z o.o. (Poland) and KB Vorspann-Technik GmbH (Germany) – all three are members of KB Group (Norway); BBR Pretensados y Tecnicas Especiales PTE, S.L. (Spain), a member of the FCC Group (Spain).

DELIVERING CERTAINTY OF OUTCOME

When embarking on any project, the thing that customers most want is certainty of outcome – they want to be sure of getting what they need. The BBR Network is always ready with the latest technology and techniques – and to work closely with the wider professional team on shaping the best and most durable construction solution.



We see more-and-more customers, such as the Norwegian roads authority in relation to the Gulli Bridge, adopting new procurement methods which call for value engineered construction. Meanwhile, in Australia the construction of new post-tensioned water tanks in an extreme climate and with sandy ground conditions brought out the best of the BBR Network's ability to innovate. It is clear that Members of the BBR Network welcome these challenges and are ready to participate – with a flexible approach and the highest level of specialist construction advice.

The Portfolio section contains numerous further examples – like the Tamina and Almonte arch bridges and two massive bridges in Malaysia – where technical excellence and teamwork have combined to deliver great outcomes for customers. Then there are achievements resulting from long-term customer relationships based on mutual trust – such as the work in New Zealand for Ports of Auckland Limited. Still other successful projects arise from the BBR Network's ability to contribute – two examples among many fine projects featured are the Q22 tower in Poland and the rock anchoring work underway in Croatia. We congratulate BBR Network Members' teams all over the world for their dedication and skill.

For us, of course, one of the most exciting recent developments is the securing of a European Technical Assessment (ETA) for the BBR VT CONA CMI Electrically Isolated Tendon (EIT). While we have launched many new technologies over the years, CONA CMI EIT represents a major step forward in providing the industry with a highly advanced and durable system which can also be monitored – you can read about this in the Technology section. Perhaps the best evidence, certainly over the last ten years, that BBR technologies and the BBR Network bring the latest and most enduring solutions can be found in the pages of CONNÆCT. Like our business, in the last decade our magazine has grown and evolved while demonstrating the best technology and techniques on the international market.

Marcel Poser
Chairman, BBR VT International Ltd

José Manuel Illescas
Vice Chairman, BBR VT International Ltd

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PUBLISHER

BBR VT International Ltd

Every effort is made to ensure that the content of this edition is accurate but the publisher accepts no responsibility for effects arising there from.
p-ISSN 1664-6606
e-ISSN 1664-6614
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ACKNOWLEDGEMENTS, SOURCES AND REFERENCES

Front cover image: The Gulli Bridge in Norway was built to endure using technology and expertise from the BBR Network. Photograph by Byggenytt.

Portfolio section

Optimized bridge construction: en.wikipedia.org
Gateway to South Eastern Europe: en.wikipedia.org, www.routesonline.com
New gateway for Mersey: Wikipedia.en, www.merseygateway.co.uk
UK's largest & most complex project: tfl.gov.uk, www.bbc.co.uk
Anchoring for agriculture: www.voda.hr

Technology section

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Vegetable based inks have been used and 85% of all waste associated with this product has been recycled.



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BUSINESS REVIEW

Reflections & outlook from BBR VT International's CEO

DURABILITY AS A DELIVERABLE

Durability is a topic which occupies the minds of many people the world over. Dictionary definitions include the words 'able to resist wear or decay well' and 'lasting' or 'enduring'. In this context, the period of time during which the expected performance must be delivered is also a critical factor. BBR VT International Ltd's CEO Antonio Caballero explores these and further aspects of 'durability' with particular relevance to the construction industry.

Some ancient structures – for example from the early Greek, Roman or Egyptian civilizations – have shown extraordinary durability over the centuries. While we may admire and wonder at these achievements, nowadays structures are designed and built under extreme cost pressure and subjected to strict environmental regulations. Most recently – and due to environmental challenges – new structures must also be more eco-friendly and sustainable.

In the modern era, approaches to construction have also changed. The amount of data to which we all now have access has grown exponentially with the continuous development of new information technologies. We can record, analyze and exploit detailed information in ways that people just a couple of generations ago would never have believed possible. Today, infrastructure is planned thoroughly – it is specified and built to be easily maintained or adapted to changed usage. This is where BBR comes into the picture.

Right technology

Durability is key for sustainability – a durable structure will deliver the expected performance over its entire service life with minimal or no maintenance. Monitoring is however required to preserve the predictability and, thus, minimize time taken to react to any maintenance issues – both of which influence the minimum safety standards for users. Although there are no objective ways to measure sustainability, it is possible to measure and monitor durability. The recently introduced BBR VT CONA CMI Electrically Isolated Tendon system (CONA CMI EIT) permits the indirect measurement of durability of post-tensioning tendons through the evaluation of electrical resistivity, allowing verification of the integrity of the plastic duct, also whether there has been ingress of water and/or aggressive chlorides – all elements which contribute to the shortening of the life expectancy of the structure. Measurements can be made during construction and during the service life of the structure which will facilitate early detection of any aggressive element which may be compromising the durability of the tendon. You can read more about CONA CMI EIT from page 80 onwards.

Fit-for-purpose

Although BBR's three founders were certainly far-sighted, could it be possible that they foresaw some of today's infrastructure challenges as they developed their technology back in the 1940s? Right from the start, it has been part of our culture to invest heavily in Research & Development to ensure that we can offer the right construction technology for the application. Our R&D process includes thorough independent testing of our technology, not only to meet current standards but also to satisfy our own internal benchmarks which are very often more stringent and have been specially developed to ensure that it is 'fit-for-purpose'. BBR post-tensioning and stay cable technologies have a proven track record for durability. For example, both De Molenbrug bridge in the Netherlands and the now iconic Sydney Tower in Australia have recently had thorough 'health checks' and, even after more than 40 years' service, the BBR stay cable systems are still delivering the expected performance and serviceability. ►





1

Quality performance

It is a well known fact that a whole chain is only as strong as the weakest link. Therefore ensuring quality in all the processes involved – from design, production, transport, storage, installation and so on – is crucial. Every single process involved in the project and every single element is important and deserves the appropriate level of attention to achieve the right level of quality.

Quality has a direct impact on durability and sustainability of systems and products. Therefore, having a solid, proven and adaptable quality management system (QMS) in place is a 'must'. The QMS must cover all aspects from factory production control right up to installation on site. As well as our development and testing processes, the BBR Factory Control Process (FPC) enables full bi-directional traceability of each single component from raw material to project execution. On page 83, you can read about the latest upgrades to our well-established internet trading and QA platform, BBR E-Trace, which supports our FPC process.

People & technology

Today, the construction industry – like most other industries – has developed to a high level of specialization among all stakeholders and therefore a high level of atomization. Thus, another important factor is continuous training and fluent communication between all the stakeholders – the producers who manufacture the systems, the designers who need to specify the right system, PT specialist who must have the right knowledge and so forth.

Correct installation – including appropriate grouting procedures – is crucial to the long-term reliable performance of BBR technology and this is why we also invest heavily in education, training and knowledge exchange. Engineers and managers within the BBR Network are great networkers and there's nothing that they enjoy more than sharing experiences – visiting each other's sites, over the telephone or a quiet drink. The pride with which they view their work is always evident – for example, at our recent training session in Amsterdam, BBR Network Members

made impressively detailed presentations on major projects in their countries to their spellbound international BBR colleagues. Quality of manufacture is also fundamental to durability and performance – this is where our well-established network of component manufacturers comes in. They all have specialized and plentiful know-how and are regularly audited by independent certification bodies. The system of attestation of conformity, having been established in our post-tensioning systems as a part of the CE requirements, is currently in place for all systems and components – not only PT – and has become a standard for supply to any part of the world. Basically, we commoditized and globalized the state-of-the-art European standards. Naturally, much credit must also go to the owners, architects and designers of structures for their foresight in actively choosing to build using the latest construction technology. By doing so, they are creating more durable structures – and investing not only in strength and durability, but also low maintenance, flexibility and protecting the environment. Of course, in the long term they are saving money too.

Asset management

Just as we humans seek medical check-ups and preventative medicines from our health professionals, a structure also needs some monitoring, control and occasionally some treatment – or repairs – to achieve its planned service life. Of course, the owners are the main party in this and must work together with specialists from our Network who will provide the right technical assistance and deliver the most optimal solution for the continued 'healthy' and safe operation of their structural assets. Durability is part of the 'value judgment' that people make when they purchase something – the value lies in the characteristics of the item and its purpose. At BBR, our business has always been about listening to what customers want and delivering the best technical support and solutions for structural resilience – our approach is as sustainable as the structures created with our technology. ●

Dr. Antonio Caballero

1 De Molenbrug on the River IJssel in the Netherlands and the iconic Sydney Tower in Australia respectively feature BBR HiAm parallel wire and BBR DINA stay cables – and the BBR technology has been proven to be functioning well, even after over 40 years' service.

TENTH ANNIVERSARY OF CONNÆCT MAGAZINE

Charting ten years of BBR Network achievements

A DECADE OF HIGHLIGHTS

The BBR Network's annual magazine – CONNÆCT – is celebrating its tenth birthday this year. BBR HQ has invited Jane Sandy, the magazine's editor, to share the background to how this now long-running magazine came about and some reflections about the culture and achievements of the BBR Network, as shown through the pages of CONNÆCT – containing reports about over 600 projects – over the past ten years.



CONNÆCT has been a ten year-long adventure which has metaphorically taken me around the world to explore some of the most exciting construction engineering achievements anyone could imagine. Not only this, I have enjoyed some excellent company along the way – there is nothing finer than working with people at the top of their game – in this case the PT Specialists within the BBR Network. Over the past decade, I have also found myself sharing their passion for a challenge – and the small selection of highlights shown here have been particularly inspiring.

LEGENDARY BBR STAY CABLE TECHNOLOGY

Staying power

Since the early days of post-tensioning, BBR Stay Cable Technology has been recognised as the most advanced and most reliable system on the market. BBR is not only the "godfather" and inventor of high fatigue resistant wire stay cables, but has also pioneered, invented and constructed the world's first project using modern parallel strand stay cables and has invented and successfully applied the world's first carbon stay cables.

Today BBR Stay Cable Technology can be used for the following applications:

- Cable stayed bridges** have been used in 170 countries, including the world's longest cable-stayed bridge, the 2,155m-long Akashi Kaikyo Bridge in Japan.
- Suspension bridges** have been used in 100 countries, where technical and economic arguments often dictate the solution. For smaller bridges, other parameters may dictate the choice of a cable stayed solution – such as reduced length of deck, construction methodology and working.
- Stayed bridges** have been used to span short spans and crossroads.

By 1971, the Olympic Stadium in Munich, Germany – with its cable supported cantilevered roof – was the world's first major arena with a cable stayed roof. In Spain, the 1992 Olympic Stadium in Seville was the world's first major arena with a cable stayed roof. In the USA, the 1994 World Trade Center in New York City was the world's first major office building with a cable stayed roof.

By 2000, it had been built. BBR Technology can be used for the same applications as well as for the following:

- Road bridges**, stadium, airport bridges and other lightweight structures to reduce an on and off load on the bridge.
- Towers** for communication, lighting, observation and antenna, as well as wind power towers can be installed using BBR Stay Cable Technology.
- High quality assistance** Extensive research testing and development efforts show BBR is the best choice for the cables.

The cables used in the construction of the Olympic Stadium in Munich, Germany – with its cable supported cantilevered roof – was the world's first major arena with a cable stayed roof. In Spain, the 1992 Olympic Stadium in Seville was the world's first major arena with a cable stayed roof. In the USA, the 1994 World Trade Center in New York City was the world's first major office building with a cable stayed roof.

STAY CABLES

▲ 2007

The first edition of CONNÆCT, back in 2007, carried a memorable article reflecting on BBR's achievement in the development of stay cable technology. They were the first to use wire stay cables in 1958, the first to use strand stay cables 10 years later and the first to use carbon stay cables in 1994. This article is memorable because, through subsequent editions of the magazine, we can see this same pioneering approach being applied to the development of still further technology and many projects.

SPORTS ARENA, LODZ, POLAND

Ring of confidence

BBR Polska – the BBR Network member in Poland – has completed an extraordinary post-tensioning task. Six Engineers of St. Bartosz's Catholic experts have a massive post-tensioned roof ring – needed to support the dome-shaped roof of the new sports arena in Lodz – was construction.

THE BUILDING
The round sports hall has a concrete structure with a steel roof and steel cover. The arena hall is approximately 100m in diameter. The roof is supported by a ring of steel, over which there are bridges leading to the arena stands which is known as the arena fish-bowl. The roof is supported by a post-tensioned concrete ring – the last of modern engineering techniques, constructed by BBR Polska.

THE BEAM
The roof support ring was on 14 concrete columns spaced every 20m at an interval of 10m apart. Inside it is a massive concrete structure which in cross-section is a concrete beam – supported by a bearing strength with 20m in height. On the outer side of the →

BBR POLSKA COMPLETED THE WORK WITH A HIGH STANDARD OF PROFESSIONALISM AND TO A HIGH TECHNICAL STANDARD – CITY OF LODZ OFFICE

The extremely demanding post-tensioning task was finished in the 2008 – has been ahead of schedule. The experts work with due regard to the excellent working relationship with developed between the BBR Polska and the main contractor. The project was a success for us – and the reference letter received from our client, the City of Lodz Office, was a great reward for our effort. This was the first time that BBR Polska had worked with a challenging and unusual working operation – we are looking forward to post-tensioning another stadium roof.

TEAM & TECHNOLOGY
OWNER: City of Lodz Office
CONTRACTOR: Skanska S.A.
DESIGNER: Inżynieria i Projektowanie Technologiczne
BBR POLSKA MEMBER
BBR POLSKA CHINA MEMBER
BBR NETWORK MEMBER
www.bbr.com

SYDNEY TOWER, AUSTRALIA

Scaling new heights

Originally conceptualised as the tallest architectural feature of the Crownpoint retail and commercial development in Sydney, the Sydney Tower Bridge was the tallest structure in the world. It is a massive concrete structure which in cross-section is a concrete beam – supported by a bearing strength with 20m in height. On the outer side of the →

CONSTRUCTION PROFILE
The cost of building Sydney Tower was A\$ 24 million – one third the cost of the Sydney Opera House – a huge project at the time. Construction of the Crownpoint development was officially started in 1997. The cable-stayed tower was designed by BBR Polska. The tower is supported by a post-tensioned concrete ring – the last of modern engineering techniques, constructed by BBR Polska.

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▼ 2014
 This article from the 2014 edition of CONNÆCT shows another example of how BBR Network Members overcome the trickiest of construction challenges. The Keppel Viaduct in Singapore was being extended, yet traffic flows on this vital route were maintained while construction work was in progress. To accommodate the project needs, among other measures the BBR team scheduled night-working and just-in-time material deliveries because of the site constraints.



▲ 2015
 The BBR Network's expertise in building overhead precast segmental viaducts for railways is shown to best advantage by this article from the 2015 edition. It describes a well-organized approach towards producing the infrastructure for stations on a new MRT line in Malaysia – and the team's ability to work with other members of the wider construction team on the project ensuring that the program is maintained.

▲ 2013
 The feature in CONNÆCT 2013 about the Danube Bridge 2 – now the New Europe Bridge – over the River Danube between Bulgaria and Romania stands out from the crowd. It was a very interesting and comprehensive account of how Spanish BBR Network Member, BBR PTE installed 208 BBR HiAm CONA stay cables, using the then new BBR HiEx CONA Saddles, as well as BBR VT CONA CMI post-tensioning.

Compelling event

The compelling event that drove production of the first issue of CONNÆCT was the massive investment that BBR VT International was making in developing the range of all-new BBR VT CONA CMX post-tensioning technology and securing European Technical Approval for each new system. With this, also came a change in BBR's business model – and the BBR Network was born. The mission, then as now, was to communicate news, deliver technical information and share achievements on an international scale – with CONNÆCT magazine as a cornerstone of that strategy. Incidentally, the unusual name of the magazine was chosen to reflect one of BBR's best known brands – CONA® – and also the concept of 'connecting' with people.

Global venture

My involvement began in August 2006 when an email from BBR VT International's then Chief Technical Officer, Marcel Poser, arrived in my inbox. In true BBR style, even this was a global collaboration – my work had been recommended by an engineer from Structural Systems (now SRG Limited) in Australia, David Pash, with whom I had worked while he was based in the UK. So, to cut a long story short, with the help of BBR Network Members, the first edition of CONNÆCT was created.

Record for the future

Since then and alongside countless other things, CONNÆCT has provided the entire BBR Network with an archive – a record of global achievements – on which everyone can draw to illustrate specific experience or track record. Like any ten year old, in many ways CONNÆCT is only just beginning to take its place in the world – with the support and input from the BBR Network, we can be sure it will continue to grow and develop. It has been an honor to share the BBR journey – and I look forward to further travels with the BBR Network in the future, through CONNÆCT. ●



1

ANNUAL BBR GLOBAL CONFERENCE, BANGKOK, THAILAND

Technical updates, networking and knowledge exchange

CONFERENCE NOTES

At the time he attended the 2015 BBR Annual Global Conference, Cezary Sternicki, now BBR HQ's Head of Product Development, had not formally joined the company. As a non-BBR family member, he explains how it was an excellent occasion to get to know the people in advance and to begin the integration process.

While my background is in the construction and civil engineering industry, the size and reach of the BBR Network around the world came as a surprise. Equally surprising was the discovery that just a few people from BBR HQ were responsible for organizing the whole of this highly successful international event.

Traditional start

The conference started with the traditional Charity Golf Tournament. This event offered a great opportunity for BBR Network Members to catch up with old friends and partners, as well as also enjoying the game and supporting those in need. The beneficiary of this year's fund-raising was the Santisuk Foundation – a non-government organization that helps children from the slums of Bangkok and surrounding area.

Conference themes

Before arriving at the conference, the BBR Network's extraordinary business model was explained to me, but I only truly understood its meaning during the technical sessions. After a warm welcome from Antonio Caballero, the CEO of BBR VT

International, there followed briefings on recent developments in Asia-Pacific (Thomas Richli), new technologies (Behzad Manshadi), supply chain (Josef Lamprecht) and marketing (Juan Maier). In the second part of these sessions, it became crystal clear to me what it is that makes the BBR Network unique. All BBR Network Members are independent business units that can freely adjust to local market requirements to best meet their clients' expectations. Hence, many of them are either highly specialized in niche construction areas or embrace larger portions of the value chain and execute general works in construction. It was valuable to learn that BBR Global Conferences are not only about the heavy stuff and technology related topics – they also promote the improvement of wider business issues. For example, we had a chance to participate in the workshop led by Professor Narayanan from the National University of Singapore about Decision Making for Leaders. Working in small teams on the tasks, unrelated to daily civil engineering topics, was a good opportunity to learn about the BBR Network from a different perspective.

1 BBR Network delegates at the 2015 Annual BBR Global Conference in Bangkok, Thailand.

2 Knowledge sharing was fostered in unconventional surroundings – including a tuk-tuk race through Bangkok and exploration of Chao Phraya River canals on long-tailed speedboats.

3 From the technical sessions, the uniqueness of the BBR Network's business model became clear.

4 Captains of the winning team and runners-up at the BBR Charity Golf Tournament shake hands. John Mo (left) who led his team to victory thanks John Taraldsen (right) whose team came a close second, while Thomas Richli (center) congratulates them both on some excellent play.

5 Following the conference, Antonio Caballero and Thomas Richli visited the Santisuk Foundation with presents for the children and donations raised through the BBR Charity Golf Tournament.



2



4



3

2015 BBR AWARD WINNERS

BBR NETWORK PROJECT OF THE YEAR

Station platforms and curved bridge for MRT & LRT Projects, Malaysia executed by BBR Construction Services (Malaysia)

BEST ARTICLE AWARD

- Winner: KB Vorspann-Technik (Austria)
Title: Fast turnaround for retail customers (Shopping center developments, Austria)
- Runner up: SRG Limited (Australia)
Title: Hitting the ground running (Paradise Dam, Australia)
- Highly commended: NASA Structural Systems LLC & Structural Systems Middle East
Title: Bridges for reasons & seasons (Bridges in Bahrain, Dubai & Oman)

BEST PHOTOGRAPHY AWARD

- Winner: BBR Contech (New Zealand)
Title: Ground floor achievements (Retail, distribution & dairy industry floor slabs, New Zealand)
- Runner up: Spännteknik AB (Sweden)
Title: Strong roots (Arjang & Tanum Wind Park projects, Sweden)
- Highly commended: BBR Construction Services (Malaysia)
Title: Fast turnaround for retail customers (IOI City Mall, Selangor, Malaysia)

Exacting agenda, relaxed evenings

During the day the agenda was exact to the minute and according to business etiquette, meanwhile the evenings had a much more relaxed atmosphere. The latter fostered knowledge and experience sharing in unconventional circumstances – for instance, during a James-Bond-like tuk-tuk race through the streets of Bangkok or exploration of Chao Phraya River canals on long-tail speedboats.

Unforgettable experience

The BBR Annual Global Conference is an unforgettable experience – in outstanding locations, with exceptional people sharing extraordinary experiences and approaches to life and many, many interesting conversations. All of this generates some magnetism around the BBR Network, which attracts unique people to join the organization – and stay. This magnetism must be strong, as there are Members who have been within the BBR family for more than 50 years – and their uniqueness was certainly in evidence on the last evening during the informal speeches and antics in the hotel bar! ●



5

NEWS HIGHLIGHTS

Events, celebrations and latest news

OUT-AND-ABOUT WITH THE BBR NETWORK

In some respects, the essence of BBR technology is about creating links or bonds and staying 'connected'. Likewise, BBR Network activities during the past year have mostly been focused on reaching out to various audiences and strengthening connections.

International conferences

The BBR Network was represented at four major conferences during 2015. The International Conference and Exhibition of Mass Construction (IEOMC) in Amman, Jordan was held in June and BBR Network Member Marwan Alkurdi & Partners had an exhibition booth.

In May, BBR Philippines sponsored the 17th ASEP-IABSE International Convention in Manila where Chee-Cheong Chang from BBR CS Malaysia and Thomas Richli from BBR HQ submitted and presented a technical paper about efficient bridge construction techniques. BBR also placed an exhibition booth at the Multi-Span Large Bridge Conference in Porto, Portugal which was attended by over 400 delegates from around the world from both academia and industry.

Meanwhile, in September, BBR and Stahlton hosted a booth at the 2015 International Association for Bridge and Structural Engineering (IABSE) Conference in Geneva.

Roadshow down under

New Zealand's major cities Auckland, Wellington and Christchurch were locations for BBR Contech's road show in July. BBR VT International supported the local team in their promotional activities with leading design consultants and construction companies. Presentations included BBR's capabilities, latest post-tensioning range with its unique benefits, and experience in bridge temporary works. Some 60 engineers attended the sessions.

Coming of age for BBR Malaysia

On 12th April 2015, BBR Malaysia celebrated their 21st Anniversary at a large function at Sunway Pyramid Resort Hotel attended by staff and guests. During the evening, 49 long-serving staff – with a total of 645 years' service between them – were recognized with special awards. To complete the formal celebrations, Managing Director Voon Yok-Lin was invited to cut a giant birthday cake and festivities continued late into the night.

- 1 The team from BBR Network Member Marwan Alkurdi & Partners pose for a photograph in their exhibition booth at the International Conference and Exhibition of Mass Construction (IEOMC) in Amman, Jordan.
- 2 Jürg Däniker talks with a delegate in the BBR and Stahlton booth at the 2015 IABSE Conference in Geneva.
- 3 In October 2015, BBR HQ moved into its new offices – which, of course, features floor slabs post-tensioned with the BBR VT CONA CMF flat system.
- 4 BBR HQ's Juan Maier and Behzad Manshadi at the BBR Network exhibition booth at the Multi-Span Large Bridge Conference in Portugal.
- 5 The new BBR Project Finder has been launched, bringing detailed information about 1,000+ projects to your desktop and can be accessed from the BBR Network website.
- 6 Voon Yok-Lin of BBR Malaysia makes the first cut in the company's massive 21st Birthday cake during celebrations in Kuala Lumpur.



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New BBR HQ

In the middle of October, BBR VT International opened the doors to its new offices – and moved in. The BBR HQ team is now operating from purpose-built modern accommodation – and happy in the knowledge that there are floor slabs post-tensioned with the BBR VT CONA CMF flat system both above and below them! The completion of this new office block which houses sister company Proceq too, also completes a significant investment by major shareholder Tectus AG.

Social media

In response to the changing trends of how companies interact and engage with their most valued customers, staff and professional associates, BBR has now established a social media presence. The BBR Network is now on Facebook, LinkedIn, Google+ and YouTube. Also, BBR news is now available through an RSS Feed from the BBR Network website – by subscribing to our newsfeed, you will ensure that you are always up to date with our latest news and announcements. All media can be accessed from links at the footer of our website.



BBR Project Finder

The new BBR Project Finder has been launched and brings detailed information about 1,000+ projects from within the massive BBR portfolio to within easy reach. The Project Finder can be accessed from the BBR Network website, by clicking on the 'Project Finder' tab, or directly at pf.bbrnetwork.com. Information in this valuable reference database may be viewed using a series of simple selection tools and resulting data on individual projects is also cross-referenced to articles in CONNÆCT magazine and external sources. Once your selection is made, you can even download a handy reference list in pdf format. More-and-more project details are being added on a continuous basis and, over coming months, we will be extending the functionality of the Project Finder with a number of new features. ●



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PERSPECTIVE

Development in bridge construction technology

EVOLUTIONARY STRENGTH



Dr.-Ing. Dipl.-Kfm. Hermann Weiher is the founder and owner of Munich-based consulting engineering firm *matrix engineering GmbH* and his specialist area of expertise is bridges. Having completed a doctoral degree in the field of prestressed concrete, his work has included several years as research assistant with the Chair of Concrete Construction at TU Munich. Meanwhile, Dr. Weiher is an active member of several national and international committees within *fib* and IABSE. For this edition of *CONNÆCT*, he shares his views on how bridge construction technology is evolving – even within an environment surrounded by regulatory requirements.

The world of construction today is largely controlled by regulations and guidelines aimed at ensuring a structure is built safely and in a way which ensures its effective performance in line with design and service objectives. This means there has to be a high degree of ‘conformity’ in the technologies applied to allow comparisons to be made by purchasers.

Regulatory developments

It was in Germany, back in the 1950s, that work began on developing a new code for post-tensioned bridges – the first of these was DIN 4227 which was published in October 1953. Obviously, this was early in the industry’s experience of post-tensioning and therefore it is not surprising that the code underwent much revision as bridge construction continued. By the 1980s, we had quite conservative building codes and these were further consolidated with the arrival of Eurocodes.

This has led, certainly in Europe, to a reluctance to innovate – the necessary bureaucracy, testing regimes and costs required to secure approvals make this an unattractive proposition for many companies. So, how have construction technology providers set about differentiating themselves?

Government-led change

Progressively, they have worked to improve their systems – with anchorages and corrosion protection being key factors.

Recently, in the USA – in Florida – we have seen a governmental shift in bridge construction technology towards external post-tensioning using strands protected with grease or wax and now the industry is trying to adapt. There was a similar situation in Germany in the 1990s when the government moved away from installing post-tensioning in the webs because of difficulties with concrete placement and also issues with corrosion. Thus, innovation is largely driven by governments who like to have a choice of suppliers offering broadly similar technologies and systems. In this environment, companies are not prepared to risk creating an entirely new technology and bearing the financial and administrative burdens this implies without guaranteed returns on their investment.

New applications

We have, however, seen a change in the type of project for which post-tensioning technology is used. Rehabilitation and strengthening of existing structures with post-tensioning has become more common – especially where traffic loads are now greater than originally envisaged and there is perhaps some age-related deterioration. It is worth mentioning that not every bridge can be strengthened using the same method – and, indeed, sometimes strengthening is not the best solution. Meanwhile, external post-tensioning is the most common and best solution for strengthening concrete

bridges, as the complete structure will be strengthened by its application. There are relatively few regulations in this area, so perhaps we will see some innovation here over coming years.

The next step is going to come with the arrival of extradosed bridges – these are very popular in the Japanese market, which was the first to adopt this type of bridge construction. It is an ideal method for dealing with special span lengths and the shape of valleys. These projects literally play to the strengths of post-tensioning – prestressing steel is very strong compared to ordinary steel and the anchorage delivers 95% of the strength of the post-tensioning tendon. Of course, corrosion protection in this situation is crucial.

The advent of ultra high performance concrete may also be a game changer. So far, we have only seen it used for single pilot projects or fairly short span prefabricated bridges.

Post-tensioning improves a bridge structurally – and we certainly never expect to see the failure under service of a post-tensioned bridge, especially if it is a continuous girder system with high redundancy. The bottom line is that post-tensioning was a great invention and, with modern advances in both anchorages and corrosion protection – which have partly been driven by mass application markets, for example, slabs or wind turbines – the systems are now really efficient. ●



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with arch closure at the Tamina Bridge, a precision approach was needed to dismantle temporary stay cables, as PT work for the bridge deck began

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the new passenger terminal at Zagreb Airport is taking shape with the help of some 37,000m² of slabs post-tensioned with BBR technology

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in a relationship stretching back 20 years, BBR Contech has ensured that Auckland's vital port facilities have received quality repair and remediation

IN THE SPOTLIGHT

BBR Adria celebrates 20th anniversary



TWO DECADES OF EXCELLENCE

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In 2016, BBR Network Member BBR Adria will be celebrating the 20th anniversary of its foundation. We asked the company's CEO, Želimir Bodiřoga, to reflect on the company's heritage and engineering achievements.

Today, BBR Adria is a leading construction engineering contractor specializing in post-tensioning operations for buildings and bridges, as well as providing remedial and marine construction engineering services. The company is building on the tradition of BBR post-tensioning in the region which stretches back over 40 years – with more than 15,000t of high value strands and tendons used in the construction of bridges, viaducts, overpasses, industrial facilities, tanks, sports halls and other buildings. One of our most senior engineers, Zdenko Mesek – now retired – had over 45 years' of working with post-tensioning technology. I always remember that he once told me that the quality and reliability of BBR post-tensioning was simply the best – and if a project was to feature post-tensioning, then it should be BBR.

Company roots

Construction of the Maslenica Bridge, which carries the A1 highway across the Maslenica Straits to the north of Zadar, marked a turning point in the history of BBR in Croatia.

BBR HQ, in collaboration with Zurich structural engineering design firm CEPAS Plan AG, provided an alternative design for arch erection. This included form travelers and featured BBRV stay and back stay cables, as well as two temporary steel pylons to stabilize the arch during construction. Construction also involved ground anchors and girders prestressed with BBR technology.

The wider professional team on the scheme included Conex of Zagreb – and also Dr Jure Radić, then a Professor, who has more recently played a key role in the design of the new Terminal at Zagreb Airport (see page 37). It was towards the end of the Maslenica project that BBR Conex d.d. was formed and the company was owned jointly by BBR HQ and Conex. Our 'birthday' was actually on 26th October 1996 and we immediately set up headquarters in Zagreb. Since then, the company's name has changed to BBR Adria and – several years later – a management buyout was agreed which has set the firm on a new and dynamic course for the future. Now, BBR Adria has 30 permanent employees and is active in Croatia, Serbia,

Slovenia, Bosnia and Herzegovina, Montenegro and other countries of former Yugoslavia. Most work has been carried out in our home market, Croatia, although there have been many projects in the other territories we cover.

Our first million m²

Since our foundation, we have installed post-tensioning for approaching 150 bridges or viaducts and many buildings, as well as providing ground anchors for some 70 projects and post-tensioning for several marina schemes.

The company's biggest achievement during recent years has been the introduction of post-tensioning for buildings in the Balkan region. When I first joined BBR Adria, back in 2004, the company was just starting work on its first such project – a large car park at Brnik Airport, near Ljubljana, Slovenia. Numerous projects of various sizes then followed and now this core activity represents up to 75% of our turnover – not including traditional bridge post-tensioning. In material terms, we have completed about a million square meters of post-tensioned slabs.



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- 1 A major business landmark for BBR in Croatia developed from the project to construct the Maslenica Bridge.
- 2 Zagreb's €100m Strojarska Towers development includes the second tallest structure in Zagreb and incorporated BBR VT CONA CMM post-tensioning for the floor slabs.
- 3 In 2003, during the restoration works at Pula's Roman Amphitheater in Croatia, BBR Adria post-tensioned the roof of what is now the olive museum, which lies beneath the arena, with the BBR CONA compact system. Photograph released into the public domain by Orlovic via Wikimedia Commons.
- 4 Re-opened in 2005, the Sloboda Bridge over the River Danube in Novi Sad, Serbia features BBR CONA stay cables. The original 1981 bridge had BBR HiAm stay cables, but was destroyed in NATO airstrikes in 1999. The bridge is believed to be the only stay cable bridge in the world to have been built twice.
- 5 The unique design of the Ptuj Bridge over the River Drava in Slovenia featured BBR VT CONA CMI and CME, internal and external, post-tensioning tendons.
- 6 Our specialist construction technology and expertise was required for the realization of the Zagreb Arena, including post-tensioning the 86 precast 'lamellas' – each 42m high – with the BBR VT CONA CMI internal system which form the building's distinctive exterior.

Public recognition

After just ten years of working with BBR technology and growing our business in the region, we were honored by a special award. We were presented with a 'First Croatian Kuna' Award for our efforts in 2006-2007. The award, from the Institute for Business Intelligence, recognized BBR Adria's position in the top 1% of best Croatian companies. Since then, we have carried out work on some of the region's highest profile projects. In 2008, we were awarded a major contract for specialist construction services for the Zagreb Arena. It was a question of honor for us to achieve the tight program because the eyes of the whole of Croatia were on us, watching and hoping we could complete the work in time for the World Handball Championships. We worked 16-hour days to install the distinctive lamellas – our team members took it in turns to work outside in the wind, snow and freezing temperatures. I also remember how we finished on 23rd December – and then ran to the stores for family Christmas

presents. Thinking about this challenging project again today, I still get goose-bumps – and for sure, I will be talking about it almost every day for the next 20 years! That same year, we enjoyed a very fine co-operation with our colleagues from fellow BBR Network Member KB Vorspann-Technik on the Ptuj Bridge project in Slovenia. More recent history can be seen through the pages of CONNÆCT, which have featured our work on the Strojarska Towers project as well as articles in this edition about the new Passenger Terminal at Zagreb Airport, the Brijesće Viaduct in Sarajevo, Project Ive Mikaca Varaždin and our geotechnical rock anchoring project for a pumping station at Bid Bosut. The excellent reputation we now enjoy is a direct result of the dedication of every member of the BBR Adria team. Their continuous attention to detail enables us to provide excellence in every aspect of customer service – and this will be the key to our continued success in the future. ●



TAMINA BRIDGE, CANTON ST GALLEN, SWITZERLAND

Arch closure & start of deck post-tensioning work

SPANNING THE GORGE

An exciting new arch bridge has been under construction in the Swiss Canton of St Gallen, as reported in *CONNÆCT* 2015 (page 26), and there will soon be a road connection for the first time between the communities of Pfäfers and Valens – set high above the stunning Tamina Gorge. Two BBR Network Members have been contributing leading edge technology and expertise to the realization of this breathtaking project. Norbert Bogensperger of KB VT (Austria) and Sascha Weder of Stahlton (Switzerland), have joined forces to deliver an update to the story. ▶

“It was an operation requiring the handling of 24-strand stay cables up to 152m long and weighing around 185t in total.”



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FACTS & FIGURES

- Deck length – 417m
- Number of piers – 5
- Height of piers – up to 55m
- Arch length – 265 m
- Number of segments – 55 (for free cantilever arch construction)
- Segment length – 5m
- Segments launched from Pfäfers side – 32
- Segments launched from Valens side – 23

A landmark event has taken place on the Tamina Bridge site since the last edition of CONNÆCT – arch closure was achieved on 28th March 2015. This means that the final segment forming the arch beneath the bridge deck has been placed. There was, of course, a major celebration as the final concrete hopper, suspended from a crane, ‘flew’ across the gorge to pour its consignment of concrete. We all took a moment to reflect on our achievement, the teamwork which had led to this point – and to think about the work still ahead of us.

As you may recall, we worked with the main contractor on alternative concepts which have benefited both the program and budget, as well as general buildability. These included using our temporary stay cables just once instead of twice, designing the post-tensioning so that less reinforcement was needed and there were less horizontal forces in the abutments. As well as making deck construction cheaper with normal falsework than with free cantilevering, it is estimated this alternative design will lead to the bridge opening taking place earlier than originally scheduled.



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- 1 The temporary stay cables were deconstructed in stages.
- 2 The upper stressing platform in early 2015, amid a snowy landscape.
- 3 Special 'Y-shaped' tendons were developed for the project by KB VT from the BBR VT CONA CMX system to fit spacing requirements in the girder-walls of the arch.
- 4 Stay cables at the second stage of the temporary pylon on the Valens side of the gorge.
- 5 In March 2015, the final segment was concreted. Here, the concrete hopper, delivered by crane to the center of the arch, is being emptied.

Photographs 1, 2, 4 & 5 courtesy of Tiefbauamt St Gallen.

Temporary stay cables

The arch springs across the gorge from two massive abutments and, during construction, was supported from the up to 100m high temporary pylons by stay cables – 31 pairs on the arch side and 24 pairs on the back span, a total of 110 stay cables.

The KB VT team, working with members of the main contractor's team, installed the cables at the rate of up to four per week on both sides of the gorge simultaneously. It was an operation requiring the handling of 24-strand stay cables up to 152m long and weighing around 185t in total.

The stay cables were fed into position using a double winch fixed in the middle of the cross-beams with guide rollers in all directions, it was like a kind of endless rope hauling system. For stressing operations, we also used two 7,000kN jacks for the main cables and ten 3,500kN lifting jacks for back span cables.

As well as being prepared with several methods of installation to allow maximum flexibility, we also had robust safety plans and procedures to protect our workers during materials handling and while working generally on such an exposed site.

“There were three main steps to our strategy for this operation – firstly safety, then delivering the technical solution and finally speed.”

Stressing

Back and main cables were stressed simultaneously in small stages. This enabled us to have permanent control of the pylon position and deflection. Deflection limits for the pylons had been clearly defined and were strictly observed, with real-time adjustments made to the stressing procedure dependent upon measured deflections. Our final stressing operation was carried out to ensure the arch position was aligned correctly to receive the next segment. ➤



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Deconstruction of stay cables

When construction of the arch had been completed, we carried out an equally complex series of actions to remove the stay cables.

There were three main steps to our strategy for this operation – firstly safety, then delivering the technical solution and finally speed.

We released the cables on the main span using specially adapted monojacks, with additional wedging for safety reasons.

The back span cables were deconstructed using lifting jacks or monojacks. Again the operation was carried out simultaneously on both pylons with the maximum difference at any one time being one pair of stay cables. We adopted releasing sequences similar to the original stressing sequences to avoid asymmetric loading of the now completed arch.

Cables were bundled near the couplers, cut and then released with the winch down the arch. Removal of the cables was carried out according to cable length. Shorter ones were simply removed by crane, while the medium sized cables were bundled, hung on the crane using special clamps then lifted and cut at the point they exited the cross beam. The longest cables were handled similarly, but cut a second time at a lower platform for safety reasons – leaving around 50m of cable to be removed later. Dismantling the stay cables took about a week per cross-beam level – with two weeks for the upper level.



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While this was a challenging stage of this wonderful project, we recognized that a complex solution such as this can only be delivered if there is mutual trust between all parties. Early involvement in the project was essential and we learned that there are no perfect ready-made concepts – developing them is a ‘live’ process requiring both engineering skills, innovation and flexibility. Together, STRABAG, Höltschi & Schurter (now Meichtry & Widmer) and KB VT formed a strong team of solutions-oriented people.

- 6 Work from the stressing platforms was undertaken in all types of weather.
- 7 The falsework structure for bridge deck construction at the top of the arch.
- 8 Concrete is delivered to the center of the bridge by crane and placed by the construction team.

Photographs 7 & 8 courtesy of Tiefbauamt St Gallen.

ALMONTE VIADUCT, CACERES, SPAIN

Arch bridge constructed with temporary stay cables

Bridge superstructure

Once the arch had been closed after the final segment pour, the main contractor began building a falsework structure to create the superstructure for the bridge deck, while also constructing the three arch supports.

As the KB VT crew were leaving the site, the team from BBR Network Member Stahlton began the installation of post-tensioning for the bridge deck which is being constructed above the arch. The deck is of a continuous box girder form and supported at 35-55m intervals.

Stahlton's work on post-tensioning the individual sections began in August. We are using the BBR VT CONA CMI internal 1506 and 1906 systems and the number of tendons placed in the box section varies between four and eight per side, depending on the span length.

Starting at the center of the bridge, deck construction is proceeding towards the abutments – in both directions at the same time. Our work also includes post-tensioning for the approach bridges on both sides of the gorge.

In total, we will be using around 180t of prestressing steel for the BBR VT CONA CMI internal tendons, some 140 anchorages and around 8km of BBR VT Plastic Duct to ensure added durability and robustness in this location which is exposed to the elements.

The completed Tamina Bridge is scheduled to open to traffic in 2017, forming the first ever direct connection across the Tamina Gorge between the Alpine villages of Pfäfers and Valens. ●

TEAM & TECHNOLOGY

Owner – Tiefbauamt Kanton St. Gallen

Main contractor – STRABAG – Erni – Meisterbau JV

Structural design – Leonhard, Andrä und Partner

Alternative design – Höltschi & Schurter (now Meichtry & Widmer Dipl. Ing ETH/SIA AG) (arch alternative for JV)

Technology – BBR VT CONA CMI internal, BBR VT Plastic Duct

BBR Network Member – Temporary stay cables: KB Vorspann-Technik GmbH (Austria), Post-tensioning: Stahlton AG (Switzerland)

WORLD RECORD ARCH BRIDGE

With the placing of the final arch keystone in August last year, Spain's Almonte Bridge claimed its place in the list of world records for having the longest span for an arched high speed railway bridge. Like Switzerland's Tamina Bridge, temporary stay cables were also used here to support construction of the arch and Spanish BBR Network Member, BBR PTE has now completed the stay cable dismantling process.

The €96m viaduct crosses the Alcantara-Garrovillas reservoir and will carry the AVE high speed railway from Madrid to Extremadura. The 996m long Almonte Viaduct is the most prominent structure on this section of high speed railway line. The viaduct is divided into three distinct parts – two access roads and one central section, the latter includes the Almonte Bridge, a 384m span concrete arch bridge.

For the construction of the arch, a total of 208 BBR HiAm CONA 5506 and 3706 stay cables were used as temporary supports while the arch segments were being cast in sequence. With the concreting of the final segment, the arch became self-supporting and the stay cables were progressively and carefully destressed before being dismantled. ●

TEAM & TECHNOLOGY

Owner – ADIF

Main contractor – FCC Construcción S.A + Conduril

Technology – BBR HiAm CONA stay

BBR Network Member – BBR PTE, S.L. (Spain)



BATANG SADONG BRIDGE, SARAWAK, MALAYSIA

Ten span balanced cantilever construction

LONGEST MULTIPLE SPAN BALANCED CANTILEVER BRIDGE



The 1.48km long Batang Sadong Bridge will be the longest multiple span balanced cantilever bridge in Malaysia. When completed in 2016, it will stimulate the growth of a new township, Sadong Jaya – and also link the townships of Simunjan and Sebuyau in Sarawak. BBR Malaysia has been engaged by the main contractor to construct the four challenging balanced cantilever piers which are on bearings, while they construct the remaining piers. In addition, BBR Malaysia is providing construction engineering services for all the piers.

Bong Su-Fah, BBR Malaysia's Construction Manager, together with Chief Prestressing Engineer George Jacob, outline the balanced cantilever method using form travelers and the necessary deflection control procedures being used to ensure the as-built levels of the bridge achieve the design levels.

Construction cycle

This massive bridge has nine piers with 10 spans in a configuration of 75 + 140 + 150 + 175 + 200 + 200 + 175 + 150 + 140 + 75m. The bridge has a deck width of 11.24m and will carry two traffic lanes in both directions. The box girder depth is 10.5m at piers, reducing to 3.6m at midspan. We are working on two piers simultaneously with two pairs of form travelers. The typical cycle time to construct a pair of left and right segments is 12 days.

Deflection control

The levels of the bridge top and bottom are taken at the following times:

- after advancing form travelers to set the levels for next segment
- after concreting of both left and right segments
- after stressing of tendons.

The deflections are calculated, plotted on a graph and then compared with the theoretical values. If the difference is significant, the level for the next segment to be cast is adjusted to bring the deflection into line with the theoretical values. Measurements must be taken early in the morning – shortly after dawn – so that temperature gradients on the bridge deck are minimized. As the top deck slab is exposed to the sun, it gets warmer compared to the cooler, concealed deck slab – thus, the bridge deck levels change during the day. The starting point for the leveling is at the axis of the piers, which forms the reference datum.



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- 1 BBR Malaysia is providing specialist construction engineering services for the 1.48km long Batang Sadong Bridge which, when completed, will be the longest multiple span balanced cantilever bridge in Malaysia.
- 2 The BBR Malaysia team working on the Batang Sadong Bridge celebrate completion of another pair of balanced cantilever segments. Typical cycle time to construct a pair of left and right segments is 12 days.

TEAM & TECHNOLOGY

Owner – Government of Malaysia

Main contractor – KACC Construction Sdn Bhd

Designer – J.H.L Konsult Sdn. Bhd.

Works contractor – PPK Sdn Bhd / BBRCS (M) Sdn Bhd

Technology – BBR CONA internal

BBR Network Member – BBR Construction Systems (M) Sdn Bhd (Malaysia)

Closure segment

After completion of the cantilevers, a gap of two meters remains between the end of two opposite cantilevers – this is to allow space for tendon stressing with multi-jacks. One form traveler is removed and re-erected on another pier. The second form traveler is launched forward to connect to the other cantilever to serve as formwork for the closure pour. Stitching beams are installed to secure the two ends of the cantilever from differential movement during concreting of the closure segment. The levels of the two ends are checked.

If the difference is significant – more than 30mm – the stiff stitching beams are used to reduce the difference in level. Vertical prestress bars are stressed with hollow jacks to pull the ends of the cantilevers up or down. Alternatively, kentledge concrete blocks might be placed on top of the deck to press the cantilever down.

When the concrete strength achieves 40MPa, the bottom and top continuity tendons are stressed. Finally, the form traveler is removed and reinstalled on another pier.

Balanced cantilever cast insitu construction using form travelers is not a fast method – but it is an efficient way to build long span bridges over deep and wide rivers. Materials, including concrete, can be delivered by barges directly to the piers. Also, as form travelers can be reused, construction costs are reduced. ●

TYPICAL SEGMENT PAIR CONSTRUCTION CYCLE

Day 1 – Day 2

After completion of cantilever tendons, left and right form travelers are advanced outwards from the pier to construct the next pair of segments. The levels of the form travelers are adjusted upwards to the required precamber level in anticipation of the downward deflection during concreting of the segment. Also considered in the precamber value is the effect of post-tensioning of the cantilever tendons causing the cantilevers to deflect upwards, but these magnitudes are relatively small compared to the deflection due to weight of concrete segments.

Calculation of the theoretical deflection takes into account the different creep and modulus of elasticity of the segments which are cast at different times.

Day 2 – Day 4

The installation of the reinforcement usually begins on the lighter segment to minimize the out of balance moment on the pier. After fixing the bottom and web reinforcement, the bottom tendon ducts and anchorages are installed.

Day 4 – Day 7

Works are carried out on the top slab soffit and outer web formwork. Next comes the fixing of top slab reinforcement and tendon ducts and top cantilever anchorages.

Day 7 – Day 9

Closing of the inner side formwork is completed and tie rods are secured to contain the high pressure during concreting.

Both segments are cast with Grade 50 concrete, on the same day, using cranes secured on barges in a 'near balanced cantilever way'. This is done by alternating the concreting between the left and right segments in several stages. The bottom slab of the lighter segment is concreted first, followed by the bottom slab of the heavier segment, and then back to the lighter segment to concrete the webs and then repeating the same on the heavier segment. Then followed by concreting the lighter segment's top slab and finally the top slab of the heavier segment.

Day 9 – Day 11

After 24 hours, the web formworks are rotated to detach from the cast concrete surface and kept moist for concrete curing. Meanwhile, strands are threaded into the empty ducts and anchor heads are fixed in preparation for stressing.

Day 11 – Day 12

When the concrete has achieved the required concrete transfer strength of 40MPa, the cantilever tendons are stressed. Upon completion of stressing, the form travelers are launched to the next segment position. Two 750t jacks are used to stress a pair of 3106 tendons or 2206 tendons. The 2206 tendons can also be stressed with 500t jacks.

GULLI BRIDGE, NORWAY

Incrementally launched river bridge

OPTIMIZED BRIDGE CONSTRUCTION

Gulli Bridge is part of the new highway between Oslo and Stockholm. The new 741m long bridge crosses Norway's longest river, the Glomma, and at the eastern end of the bridge is the city of Kongsvinger – home of Norwegian BBR Network Member, KB Spennteknikk. Stig Solbjør, Technical Manager, describes the bridge's setting, how it was designed under new guidelines and constructed to be durable.



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- 1 The 741m long Gulli Bridge, part of the new Oslo-Stockholm highway, crosses the River Glomma close to Norwegian BBR Network Member KB Spennteknikk's head office in Kongsvinger. Photograph by Byggenytt.
- 2 Aerial view of the completed Gulli Bridge where the team supplied, installed and stressed 19,000m of BBR VT CONA CMI PT tendons and supplied purpose-made TOBE pot bearings for installation after the incremental launching operation. Photograph by Jon Ivar Søhus.
- 3 The value engineering exercise resulted in the selection of incremental launching as the bridge building method. Photograph courtesy of Grzegorz Gucwa, Skanska.



3

At 621km long and with a drainage basin covering 13% of the country, the Glomma – or Glåma – is Norway's longest and largest river. It runs from Lake Aursund near Røros in Sør-Trøndelag and ends when it flows into the Oslofjord at Fredrikstad. Major tributaries include the Vormå river, which runs from Lake Mjøsa – Norway's largest lake – and joins the Glomma at Nes. This is a particularly significant connection because the River Lågen ends in Lake Mjøsa where drainage waters from the large Gudbrandsdal valley collect – and thereby, via the Vormå, the River Glomma's flow is significantly increased. Historically, the Glomma has been a major transportation route – famous for once being Norway's leading log floating river as it flows through some of the richest forest districts. Over the years, the combination of raw materials, water power and easy transport has fostered development of industry along the Glomma. Some of the country's largest manufacturing and processing installations are found around the river's mouth, where supplies of timber and hydropower have been supported by excellent port facilities.

Optimized bridge design

The Gulli Bridge was designed under new guidelines set out by the Norwegian Road Department. Value engineering workshops were held between the selected contractor and client to find an optimized solution for the construction project with respect to program and budget. The cost savings are then shared between the client and contractor.

From this value engineering exercise, came a proposal by the contractor to use the incremental launching method – a common choice in European countries other than Norway – for the bridge's construction.

Bridge design

The collaboration between the owner and contractor resulted in a slight change in the curvature of the bridge and extended spans from 40 to 50m, which reduced the number of columns. The River Glomma has a high water flow and difficult ground conditions due to spring flooding. In addition, the incremental launching method simplified the crossing of the railway, which passes under the bridge.

The bridge has 32 precast concrete elements with a unit length of 25m – all built in the production plant, a temporary factory created on site, on the northern side of the river – and incrementally launched in two week cycles. We supplied, installed and stressed 19,000m of BBR VT CONA CMI 1206 post-tensioning tendons and assisted the main contractor with personnel for the incremental launching. We also supplied 32 purpose-made TOBE® FR-4 pot bearings that were installed after the incremental launching process and two ETIC EJF 500 expansion joints – one at each end of the bridge, produced by the French BBR Network Member. ●

TEAM & TECHNOLOGY

Owner – Statens Vegvesen

Main contractor – Skanska Norge AS

Consultant – Dr. Ing. Aas Jakobsen

Technology – BBR VT CONA CMI internal, bearing, expansion joint

BBR Network Member – KB Spennteknikk AS (Norway)



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MERSEY GATEWAY BRIDGE, RUNCORN-WIDNES, CHESHIRE, ENGLAND

BBR post-tensioning for bridge deck

NEW GATEWAY FOR MERSEY

A second road crossing over the River Mersey in North West England has been a long held aspiration for many and now the new bridge is taking shape. Roger Stables, of BBR Network Member Structural Systems (UK) Limited, tells the story of the bridge's history and his company's role in the construction project.

The River Mersey flows for some 70 miles from its source near the town of Stockport to the city of Liverpool before flowing into the Irish Sea. On its journey, the river narrows between Runcorn and Widnes, in the Borough of Halton, and it was here that the Silver Jubilee Bridge was first opened in 1961. As the only vehicular crossing of the Mersey in the Halton area, and with the increase in road traffic over the last 50+ years, the road bridge – and local highway network – has been under severe pressure despite bridge widening and strengthening work in the 1970s. Now, a major new six-lane toll bridge is under construction between Widnes on the northern bank of the river and Runcorn

on the southern side, around 1.5km to the east of the Silver Jubilee Bridge. More than just forging a connection and easing congestion, it is hoped that the bridge will be a catalyst for regeneration and new and inward investment in the local area and north west as a whole. The Merseylink Consortium – consisting of sponsors Macquarie Capital (Australia), FCC Construcción S.A. (Spain) and BBGI – was selected as preferred bidder for the project in June 2013 and will be responsible for the design, building, financing and operation of the bridge for 30 years. Financial close was achieved in 2014 and construction work began on 7th May the same year.

1 Artist's impression of the completed Mersey Gateway Bridge between Runcorn and Widnes.

2 Aerial view of bridge construction site with completed trestle bridge and showing all three cofferdam sites, as well as the Silver Jubilee Bridge in background.

3 Aerial view of the north cofferdam where excavation for a pylon base is underway.

Photographs 1, 2 & 3 courtesy of www.merseygateway.co.uk.



“This particular design was chosen as it maximizes benefits for users and the local community while minimizing impact on the environment.”



3

Construction methodology

Three cofferdams were built in the river to allow excavation for the bases of the bridge pylons. Meanwhile, a temporary trestle bridge was built to allow access to the site. Span-by-span construction of the main bridge deck began in autumn 2015. The team is using Europe’s longest Movable Scaffolding System (MSS) – which measures 157m long and weighs in at around 1,700t. Named ‘Trinity’ to reflect the unusual three pylon design and the three companies within the Merseylink Civil Contractors Joint Venture – Kier Infrastructure and Overseas Limited, Samsung C&T ECUK Limited and FCC Construcción S.A. – the MSS is capable of casting spans up to 70m long.

Post-tensioning technology

Specialist companies BBR PTE S.L., Structural Systems (UK) Ltd and VSL Systems (UK) Ltd have formed a joint venture known as ‘BSV Mersey JV’ in order to offer the Mersey Gateway project with what we believe to be the most highly skilled and optimized specialist service within our field – an approach considered essential for such a high profile and technically challenging project. When completed in 2017, the new bridge will carry three traffic lanes across the River Mersey in each direction and link Runcorn’s Central Expressway with main highways to the M62 motorway and towards Liverpool. ●

Bridge design

The Mersey Gateway Bridge is of a cable-stayed design, similar to the Second Severn Crossing Bridge – but with three pylons instead of two. The outer two pylons will be 110m (north) and 125m high (south), while the central pylon will be shorter, at 80m high. The bridge will have a river span of 1km and, with the approach viaducts on either side, will have a total length of 2.13km. This particular design was chosen as it maximizes benefits for users and the local community while minimizing impact on the environment.

TEAM & TECHNOLOGY

- DBFO** – Merseylink Limited
- Main contractor** – Merseylink Civil Contractors Joint Venture: Kier Infrastructure and Overseas Limited, Samsung C&T ECUK Limited and FCC Construcción S.A.
- Structural designers** – Merseylink Design Joint Venture: Flint & Neill, Aecom, Eptisa and Fhecor
- Technology** – BBR VT CONA CMI internal
- BBR Network Member** – Structural Systems (UK) Limited & BBR PTE (Spain)

BRIJEŠĆE VIADUCT, SARAJEVO, BOSNIA AND HERZEGOVINA

New road bridge relieves traffic in capital city

DETOUR AROUND SARAJEVO

At around 720m long, the Briješće Viaduct is a key component of the 10km Sarajevo Bypass scheme which will reduce traffic congestion in the city center and connect the city with the A1 highway. The viaduct is located on the 4km approach road which connects the Bypass to Sarajevo. Tomislav Lopandić of BBR Adria, describes his company's work on the project.

- 1 The 720m long, 11-span Briješće Viaduct is a key component of the 10km Sarajevo Bypass scheme which will reduce traffic congestion in the city center and connect the city with the A1 highway.
- 2 The viaduct was post-tensioned in stages using BBR VT CONA CMI internal tendons consisting of 14 x 15.7mm diameter strands.



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Construction of the Sarajevo Bypass was divided into three sections and the Briješće Viaduct is in Lot 2 which covers the stretch from Butila junction to Briješće. After the new road crosses the Briješće Viaduct, it splits into two – one road goes to Stup and the other to Rajlovac.

Project overview

The viaduct is designed for speeds of up to 100km/h and is 11.75m wide which allows two 3.5m wide lanes and a 2.5m wide emergency lane, along with other features. In all, we have been working on six separate structural elements for this viaduct which crosses the roundabout at Briješće, the M13 road and a dual track railway line. The viaduct has 11 spans, supported at between 28 and 35m intervals, and was built in two separate packages. Package 1 has two independent carriageways carried on bridges, the left carriageway is 360m long and the right is 363m. It also features access and exit ramps which have two 3.5m wide lanes and are each 125m long. Package 2, consists of two 359m long parallel structures. All structures were built in stages – the main viaduct in 11 stages and the ramps in four. In total, 1,691m of road has been created for the project.

Post-tensioning & stressing

We post-tensioned the viaduct in stages using BBR VT CONA CMI internal tendons consisting of 14 x 15.7mm diameter strands. The BBR Adria team carried out tendon stressing four days after casting the deck – or after the C35/45 concrete had achieved a minimum of 70% of its design strength. The higher concrete strength permitted the use of less local anti-bursting reinforcement, thus reducing congestion. The tendons were each stressed to a force of 2,856kN. Around 653t of 1,860MPa prestressing steel was installed in the viaduct.

Timescales & completion

The first phase of construction started towards the end of 2013 and was completed in early 2014. In this period we executed 10 slabs. With the selection of a new main contractor in April 2015, the second phase of construction began and a further 42 slabs had been constructed by the time it finished in October 2015. Completion of the Briješće Viaduct will not only improve traffic conditions on other access roads around Sarajevo, but also offer motorists a faster and more comfortable journey. For BBR Adria, the Briješće Viaduct project has been an exceptional logistical and technological success – even in the face of a short program and involving the execution of up to four separate slabs at the same time. Installation, tensioning and grouting were performed by one engineer and three BBR specialists. This project has clearly demonstrated the experience and resourcefulness that the BBR Adria team is able to bring to every new project. ●

TEAM & TECHNOLOGY

Owner – JP CESTE BiH Federation
Main contractor – GP ŽGP d.d.
Designers – Ipsa Institut, Trasa d.o.o.
Technology – BBR VT CONA CMI internal
BBR Network Member – BBR Adria d.o.o. (Croatia)



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BATANG SEMARIANG BRIDGE, SARAWAK, MALAYSIA

High capacity self-advancing beam launcher saves on program & budget

SELF-ADVANCING TO SUCCESS

The Batang Semariang Bridge project was initiated by the state government of Sarawak as part of a new route to link Petrajaya – the new state government administration hub – to Kuching, capital of Sarawak. BBR Malaysia's Project Manager Chok Moi Chun and Assistant Technical Manager Tie King Bang describe how the construction methodology was changed to enable fast and cost-effective construction of this new multi-span river bridge.

The overall bridge length is 300m and consists of eight equal spans of 37.5m each, crossing over the Semariang River. The bridge is designed as a continuous span structure with expansion joints only at the two abutments. The 14.5m wide deck accommodates two traffic lanes in each direction. Each span comprises three prestressed box shaped beams with each precast beam weighing 170t. Based on our good track record and construction engineering experience, we were awarded the whole bridge package – from piling, precasting of beams, post-tensioning, beam launching to completion of the bridge superstructure.

Optimized construction methodology

The original construction method involved casting the U-section of the box-shaped beam only, followed by partial stressing

of tendons and then launching the U-shape beam to the designated span using mobile cranes. After this, the deck slab would be cast and finished with second stage stressing works. The purpose of this was to reduce the launching weight and thus avoid the costs, time and risks involved in using high capacity mobile cranes and heavy temporary bridge access. In this region, 40m long precast beams are commonly used and typically they weigh 100-130t – and only rarely as much as 170t. The improved approach we adopted involves use of a beam launcher with capacity to launch 40m long precast beams weighing up to 180t. With the high lifting capacity of the beam launcher, thanks to the triangular truss system, the box shaped beams could be cast in full section and stressed to the required force in just one stage at the casting yard.

Tendon configuration

Six BBR CONA internal bonded tendons are installed in each post-tensioned precast box girder beam. As the re-engineered box section has a higher moment of inertia and stiffness, all the tendons can be stressed to the required design force in one stage with a 500t capacity multijack before the beam is delivered to the beam launcher. After launching the three beams, the end and intermediate diaphragm beams and side stitching of the deck slab are constructed. A pair of BBR CONA internal tendons in each diaphragm beam is stressed before the deck is completed and stable, then the beam launcher advances to the next span.

- 1 The bridge pier crossheads support the three boxed beams – and were also designed to handle temporary loads from beam launching operations.
- 2 BBR Malaysia's alternative construction proposal for the Batang Semariang Bridge involved using a beam launcher to handle the 40m long precast beams which weigh up to 180t.

TEAM & TECHNOLOGY

Owner – Government of Malaysia

Main contractor – Zecon Dredging Sdn Bhd

Designer – J.K. Bersatu Sdn. Bhd.

Bridge subcontractor – BBR CS (M) Sdn Bhd

Technology – BBR CONA internal

BBR Network Member – BBR Construction Systems (M) Sdn Bhd (Malaysia)

Bridge sub-structure

Each bridge pier is supported by three 1.2m diameter vertical bored piles and two 0.75m diameter raked bored piles for lateral stability. The three vertical piles continue above the pile cap to form the vertical piers which support the crosshead. The crosshead supports the three boxed beams – and was also designed to handle the temporary loads from the beam launching operation. The span-by-span construction method means that the offset point of applied load from the launching works and one side span are unavoidable. The crosshead is designed to resist torsion force at every pier support. Also, the axial and bending capacity of the high piers were analyzed and checked based on eccentric load from the launching works. The beam seating area on the crosshead is enlarged to reduce localized compressive stress on the concrete.

Self-advancing beam launcher

Our existing beam launcher was upgraded – the 140t winches were replaced with a 180t system and the launcher was equipped with the facility to advance to the next span by its own self-advancing mechanism. The beam launcher is 72m long for cantilevering to the front pier and is comprised of double trusses, each truss is divided into six equal modules connected with high tensile bars. It has two main support legs and three auxiliary support legs attached to hydraulic jacks and a motorized trolley system for

level adjustment and transverse shifting of the beam launcher. It also has an additional feature which enables beam lifting using a single triangular truss. This is useful when the need arises to deliver the outer beam towards the end of a crosshead without extending the transverse rail or having additional temporary support.

Construction cycle & program

The construction cycle for each span is approximately one month and can be divided into three main stages – self-advancing of beam launcher, beam launching works and in-situ construction works. Self-advancing of the beam launcher and launching of three precast box girder beams takes seven days. In-situ construction, involving construction of diaphragm beam and deck slab stitch, requires approximately three weeks – the beam launcher then advances to the next span. The overall construction program for this bridge is 15 months. Six months' program time was allocated for piling works up to substructure level and eight months for launching works and in-situ construction of the bridge superstructure. Construction time and costs are greatly reduced by using a self-advancing high capacity beam launcher for multiple span bridge construction. As it is self-advancing, mobile cranes are not needed to shift the beam launcher. With the high load capacity of the beam launcher, heavier beams can be launched and tendon stressing reduced to one stage instead of two. ●





PROJECT IN PICTURES

Rail Bridge, Otaio River, New Zealand

GOING WITH THE FLOW

A new rail bridge in New Zealand is expected to perform for more than 100 years – and for that some credit must go to the CONA CMX post-tensioning range of solutions.

The 126m bridge spans the Otaio River in the South Canterbury region of New Zealand’s South Island. As reported in CONNÆCT 2015, it replaces a steel and timber structure built more than a century ago that, according to rail infrastructure manager KiwiRail, was no longer economical to repair.

The new bridge, which is located about six meters downstream of the old one, is constructed of concrete beams and columns and nine spans of 14m-long precast concrete deck units. Working with main contractor McConnell Dowell Constructors and engineering specialist Novare Design,

BBR Contech supplied, installed, stressed and grouted 12 post-tensioned BBR VT CONA CMI 0906 multi-strand tendons into each unit.

The process took around four months and the new NZ\$5 million bridge opened for business soon afterwards. Its new location, which is better aligned with the river’s channels, should help to prevent future damage during major floods. Nothing remains of the old Otaio rail bridge today, but that’s progress for you. Instead, the new bridge is conveying freight to places north and south – and, all going well, will carry on doing so for another century. ●

TEAM & TECHNOLOGY

- Owner – KiwiRail
- Main contractor – McConnell Dowell Constructors
- Structural engineer – Novare Design
- Technology – BBR VT CONA CMI internal
- BBR Network Member – BBR Contech (New Zealand)

NEW PASSENGER TERMINAL, INTERNATIONAL AIRPORT ZAGREB, CROATIA

Post-tensioned floor slabs as alternative design proposal

GATEWAY TO SOUTH EASTERN EUROPE

Zagreb's Pleso Airport first opened in 1962 and both the runway and passenger terminal were extended significantly in the 1970s. However, since the turn of the century, the number of passengers passing through has doubled to around 2.5 million per year. While recent expansion of the existing terminal has eased pressure on facilities, work on the construction of a second passenger terminal – capable of handling 5 million passengers annually – is now underway. Goran Tomišić of BBR Adria reports on the project. ►

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An international competition was held to find the best design for the new terminal and the proposal put forward by a consortium of Croatian architects – including IGH d.d. (Civil Engineering Institute of Croatia) and architects Velimir Neidhardt, Branko Kincl and Jure Radić – was declared the winning solution. Their undulating form for the building was inspired by the local landscape and reflects the shape of the mountainous backdrop of the city.

The project is funded by French consortium ZAIC – consisting of Aéroport de Paris and Bâtiment International Airport – who were awarded the concession by the Croatian government to build the new passenger terminal and manage the airport for 30 years. The design and build contract was let to the Međunarodna Zračna Luka Zagreb and Bouygues Bâtiment International Joint Venture.



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- 1 To increase capacity at Zagreb's Pleso Airport, a second passenger terminal – capable of handling five million passengers annually – is now under construction.
- 2 By April 2015, work had begun on installation of the frame for the undulating roof form and was well-advanced by the end of June.
- 3 The south, east and west façades are designed as flat aluminum curtain walls with structural glazing.
- 4 The new passenger terminal at Pleso Airport in Zagreb begins to take shape.



“The structure was initially designed to be of prefabricated concrete construction, however, following a proposal by the contractor, it was rapidly redesigned to be of monolithic post-tensioned construction.”

Design & layout

The new passenger terminal is a four level building comprising a rectangular main section and extending into two asymmetrical wings – the western for international departures and arrivals, the eastern for domestic traffic. Lower levels will be used for arrivals and the upper for departures. On the northern façade, there are eight passenger boarding bridges connecting with 16 departure gates inside the building. The structural frame of the building consists of circular reinforced concrete columns, post-tensioned concrete beams and slabs, plus four reinforced concrete communications cores.

Above the concrete structure is a rippling steel space frame which links the roof of the main building and passenger boarding bridges with the northern façade. The south, east and west façades are designed as flat aluminum curtain walls with structural glazing. The roof is partially glazed and partially covered with the very latest in aluminum cladding.

Construction overview

The total area of the corrugated steel roof is 25,000m², while three concrete floors – not including the ground slab – have an area of about 45,000m². The central section of the terminal building has a footprint of 130 x 136m – and there are no expansion joints due to the layout of seismic walls located near the very ends of the ground plan.

The structure was initially designed to be of prefabricated concrete construction, however, following a proposal by the contractor, it was rapidly redesigned to be of monolithic post-tensioned construction. ➤



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FACTS & FIGURES

- 37,000m² post-tensioned slabs
- 8,000m² reinforced concrete slabs
- 25,000m² roof
- 280t BBR VT CONA CMM tendons
- 5,000t reinforcement bar

Ceilings & floors

The horizontal ceiling structure was resolved to be of monolithic post-tensioned construction. All three levels of ceiling panels have longitudinal and transverse pouring strips. These pouring strips reduce the surface area of the first phase of construction on sections up to 60-70m long. The predominant grid sizes are 7.2 x 14.4m for the ground floor and 14.4 x 14.4m for first and second floors.

Post-tensioned slabs were designed as shallow, wide beams. The first floor slab has beams running in the longer 14.4m direction.

The beams here measure 1,600 x 550mm and between them is an 180mm thick slab. Beams in the upper level floors sit on a 14.4 x 14.4m column grid. They extend in both directions and are 3,000mm wide by 550mm deep, with a 250mm thick infill slab. Larger openings that interrupt the continuity of these beams are resolved with reinforcement at the edge of the openings, so that loads are transferred to the adjacent beams. One exception is where the pillars of the top floor are offset from the main axis and, here, their forces are taken by 3,000 x 850mm reinforced beams.



- 5 The roof is partially glazed and partially covered with the very latest in aluminum cladding.
- 6 A total of 280t of steel prestressing strand was used for the BBR VT CONA CMM monostrand tendons.
- 7 Post-tensioned slabs were designed as shallow, wide beams and, as pictured here, for the first and second floors, arranged on a 14.4m x 14.4m grid.
- 8 By October 2014, work on site had reached a peak and BBR Adria was installing post-tensioning for several slabs at the same time.

Post-tensioning

We used around 280t of BBR VT CONA CMM tendons with strand of 150mm² cross-sectional area and 1,860MPa characteristic tensile strength. There were many benefits offered to the project by this BBR technology – including factory provided corrosion protection, speed and ease of laying, larger tendon eccentricity and small friction losses which allowed prestressing of the larger 60-70m sections. Proportionately, more tendons are grouped in the reinforced beams, while fewer tendons pass through the slabs at equal distances. In the beams, the tendons are profiled using a parabolic curve. The radius of curvature of the tendons above the columns is $R = 4\text{m}$, which gives an optimal minimum breaking load (MBL). For the 180 and 250mm thick slabs, outside of beam zones, we adopted the free tendon layout which significantly simplifies and accelerates installation. By request of the investor, the tendons in the 3,000 x 550mm beams near columns have been grouped in such a way that, if necessary at some stage in the future, four 400 x 400mm openings could be created without having to cut or interfere with the PT tendons. Due to their high stiffness, some seismic walls will subsequently be made monolithic with the slab and, until then, will rely on temporary short columns.



8

Completion of new terminal

Construction work began in summer 2014 and concrete construction was completed in February/March 2015. The BBR Adria team has finished its tasks, but work continues around the site on the external building envelope, roads to connect the new facility to the existing road network and, finally, there will be a testing and commissioning phase. We are all looking forward – with great excitement – to late 2016, when the new passenger terminal is scheduled to open for business. ●

TEAM & TECHNOLOGY

Investor – International Airport Zagreb
Architects – IGH dd (Civil Engineering Institute of Croatia), Velimir Neidhardt, Branko Kincl and Jure Radić
Main contractor – KAMGRAD d.o.o.
Structural designers – Dr.sc. Jure Radić, Milan Crnogorac, Predrag Presečki (PT slabs)
Technology – BBR VT CONA CMM monostrand
BBR Network Member – BBR Adria d.o.o. (Croatia)

WIRI INLAND PORT, AUCKLAND, NEW ZEALAND

Post-tensioned slabs for cold storage

CONNECTING SEA & LAND

When you have a port management company as a client, you would quite naturally expect to work by the sea. Not so in New Zealand, where BBR Contech's long-standing partnership with Ports of Auckland Ltd (POAL) and concrete floor specialist Conslab extended in 2015 to an inland project – and a port of a very different kind.

Originally established around 2005, the Wiri Inland Port is a 15-hectare freight handling hub located in South Auckland. It is about 25km from the seaport, but crucially close to two key state highways and the North Island's main trunk railway line.

Ground-breaking service

The hub exploits these attributes to provide a ground-breaking service for exporters and importers of containerized goods – the ability to drop off and pick up their containers without having to negotiate the often congested Auckland motorways to get to and from the central-city seaport. They can use road and rail to transport their containers in or out of the hub, while the containers are moved between the seaport and the hub via a dedicated rail siding, usually at night and during the weekends.

Completing the process, the hub offers all the e-commerce and border clearance services available at the seaport, which means containers can be unsealed and their goods dispatched directly to points north and south.

The benefits of this innovative approach are significant – a dramatic reduction in the number of central city truck trips – and therefore reduced carbon emissions and traffic delays for other road users – a more convenient drop-off and pick-up location for cargo owners, a more efficient supply chain, less cargo handling and an opportunity for POAL to find more

productive uses for valuable real estate formerly used to store empty containers. "The Wiri Inland Port has proved a great investment," says Pete Algie, Asset Manager for POAL. "When the rail siding opened in 2010 we ran four trains a week between the seaport and the hub, today we run 21 and are looking to increase that number further."



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“It was no easy task, with a tightly constrained site and a single entry point making access a challenge for all the contractors involved.”

New cold store development

The latest development at the hub – and the reason for the BBR Contech project – is an 11,800m² cold store which is capable of handling around 20,000 pallets of frozen goods.

Working with Conslab and main contractor Ebert Construction, BBR Contech installed post-tensioning into four slabs for the cold store between June and August 2015 – two were 175mm thick and two were 190mm, the latter was required to hold heavy-duty pallet racking. It was no easy task, with a tightly constrained site and a single entry point making access a challenge for all the contractors involved.

“The work was complicated by the fact that the foundation for the slab was a layer of polystyrene insulation,” says Terry Palmer, BBR Contech Project Manager.

“There was no choice but to pump the concrete through hoses from the outside to avoid damaging the insulation and the PT ducts. It was extremely labor intensive!”

Pete Algie says that, while the Wiri Inland Port project was very different from BBR Contech’s typical seaport work for POAL (see page 70), the two stories demonstrate the range of services that BBR Contech performs across the POAL asset base. ●



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- 1 The latest development at Wiri Inland Port required construction of four post-tensioned slabs.
- 2 Two post-tensioned slabs were 175mm thick and two were 190mm – the latter has been designed to support heavy duty pallet racking.
- 3 Construction of the post-tensioned slabs was complicated as the foundation for the slab was a layer of polystyrene, so concrete was pumped from the outside to avoid damage to the insulation and PT ducts.

TEAM & TECHNOLOGY

- Owner** – Ports of Auckland Ltd
- Main contractor** – Ebert Construction
- Concrete flooring specialist** – Conslab
- Technology** – BBR CONA flat
- BBR Network Member** – BBR Contech (New Zealand)

PROJECT HIGHLIGHTS

Post-tensioned slab solutions for buildings

GLOBAL APPEAL & VALUE

TEAM & TECHNOLOGY

- 1 Developer** – VMD PROMET d.o.o.
Main contractor – TEAM d.d.
Designers – Krešimir Tarnik, Predrag Presečki & Goran Tomišić (PT slabs)
Technology – BBR VT CONA CMM monostrand
BBR Network Member – BBR Adria d.o.o.

- 2 Owner** – Knowledge Vision Sdn Bhd
Main contractor – Pembinaan Yuen Seng Sdn Bhd
Technology – BBR CONA internal
BBR Network Member – BBR Construction Systems (M) Sdn Bhd (Malaysia)

- 3 Owner** – Government of Western Australia
Design & build contractor – John Holland Pty Ltd
Technology – BBR VT CONA CMI internal
BBR Network Member – SRG Limited (Australia)

- 4 Owner** – Sistema Plastics
Main contractor – Haydn & Rollett
Concrete flooring specialist – Conslab
Technology – BBR CONA flat
BBR Network Member – BBR Contech (New Zealand)

- 5 Owner** – Government of Western Australia
Main contractor – City Busport Alliance (Perth Transport Authority, Brookfield Multiplex and BG&E)
Technology – BBR VT CONA CMI internal
BBR Network Member – SRG Limited (Australia)

- 6 Developer** – Halter AG
Main contractor – Feldmann Bau AG + Estermann AG
Consulting engineer – Suisseplan Ingenieure AG
Technology – BBR VT CONA CMI internal
BBR Network Member – Stahlton AG (Switzerland)

The advantages of post-tensioned ground and floor slabs, as well as transfer floor plates, is being recognized all around the world. The benefits – whether concerning aesthetics and practicalities, or time and cost – are being delivered by BBR Network Members whose skill is also acknowledged by their regular customers.



1 Maximizing space with PT
 Following the Strojarska Towers project, VMD Promet and BBR Adria, have continued their successful cooperation for the Project Graharova scheme, also in Zagreb, Croatia. The building consists of two underground garages and four to six upper business and residential floors. The underground structure is square shaped, while the upper part consists of an L-shaped residential/business area and square shaped retail space. The 4,500m² foundation slab and the underground garage ceilings were post-tensioned. The ceiling of the retail space has also been constructed as a post-tensioned slab. BBR VT CONA CMM monostrand technology was installed on the project. The large spans – of up to 17.5m – mean there are fewer columns in the garages, so maneuvering is much easier – and the retail area is more spacious.

2 Advantages for all
 BBR Malaysia’s Yan Mung Chung designed the 1.5m thick post-tensioned transfer floor, using BBR CONA internal tendons, for the Almyra Residence – four 30-storey tower blocks over a common podium car park, part of the Bandar Putri@Bangi development, south of Kuala Lumpur. The PT transfer floor offers a reduced structural depth and aesthetic flat slab soffit, as well as reducing formwork, props and backprop costs and construction program, compared with the originally planned 1.8m deep reinforced concrete beams. It is no wonder that structures designed with post-tensioned flat slabs are increasingly common in this region. A two stage casting was adopted whereby one layer of concrete was cast and first tendons stressed to support the weight of the second stage concrete. For columns with shear loads, drop caps up to 600mm deep were used to increase the punching shear capacity.

1 Project Graharova, Zagreb, Croatia.
 2 Almyra Residence, Bandar Putri@Bangi development, Malaysia.
 3 Perth Childrens’ Hospital, Perth, Western Australia.
 4 Sistema Plastics Warehouse, New Zealand.
 5 Perth Busport, Perth, Western Australia.
 6 Mall of Switzerland, Ebikon, Switzerland.

“We believe in surrounding ourselves with competent, trusted partners. These guys [Conslab & BBR Contech] have consistently delivered in terms of performance and value and they meet – and often exceed – our expectations. The longevity of our partnership reflects this – they’re the experts at what they do and are as committed as we are to maintaining a healthy and rewarding relationship.”

Kim Barrett, Managing Director, Haydn & Rollett, New Zealand



3 Major & complex work

The Perth Children’s Hospital will replace the existing Princess Margaret Hospital for children, built over 100 years ago. SRG was contracted to install 220t of prestressing strands in the post-tensioned beams for 120,000m² of suspended floors over nine storeys. Works also included supply and installation, sealing and grouting of almost 3,000m of temporary movement joints across the project. The project was broken into four main work areas and was serviced by five tower cranes. The complex nature of the project and space constraints on site created many challenges throughout construction – including ‘just-in-time’ material deliveries, craneage coordination and coordination between construction zones and other trades.

4 Cementing a relationship

Over the past 15 years, New Zealand’s BBR Contech has formed a great working relationship with concrete flooring specialist Conslab and, through Conslab, property developer and builder Haydn & Rollett. This relationship has led to some 27 post-tensioned flooring projects together, covering an area of 280,000m². In 2015, a commission for a 45,000m² post-tensioned slab for a factory and distribution center in Auckland, broke through the 300,000m² mark for this partnership – and took BBR Contech’s total tally of PT slab projects to more than two million square meters! This most recent project was the largest ever undertaken for the New Zealand-based manufacturing company, Sistema Plastics. The flooring project involved 14 pours to create a 170mm thick, 300m x 150m structure comprising coupled slabs with two permanent movement joints in the longest direction. It required more than 200t of 15.2mm strand – a massive investment that will ensure a strong, robust surface for both vehicle traffic and a very high-spec automated racking system that is the largest in New Zealand.



5 Top down construction

Australian BBR Network Member SRG was contracted to provide the post-tensioning to the roof slab and entry portals of the new underground Perth Busport, part of the Perth City Link Project. Top down construction was chosen because of the site’s close proximity to the recently completed rail tunnel – and because it does not require extensive formwork. Prior to excavation beneath to create the main concourse, the 800mm thick roof slab was constructed on the ground. It covers an area of approximately 213 x 46m with no movement joints and is designed to support future multi-storey buildings above. The project involved placing 9,000m³ of concrete and 1,500t of rebar. The post-tensioning works included installation of BBR VT CONA CMI post-tensioning tendons which were up to 46m long and required 150t of steel prestressing strand.



6 Largest in Switzerland

With 46,000m² of retail space and around 140 shops, Mall of Switzerland in Ebikon is set to become the largest shopping destination in central Switzerland. An adjoining car park with 1,600 spaces is also under construction. In addition, 12 cinema screens, a hotel and apartments are planned for the site. BBR Network Member Stahlton is using the BBR VT CONA CMI internal system, with both fixed and movable anchors, to provide post-tensioned beams and floor slabs for the shopping center and one-way post-tensioned floor slabs for the car park. ●



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IVE MIKACA, VARAŽDIN, CROATIA

Transfer plate construction for diversity of building use

PRACTICAL SOLUTION FOR MULTI-FUNCTIONAL BUILDINGS

In modern buildings designed for residential and commercial use, the vertical axis of the walls and columns must often allow three different uses of the structure. Firstly, there is an underground garage, next a business area mostly placed on ground floor and thirdly, several residential floors. Goran Tomišić of BBR Adria describes the solution his company has been successfully providing for such buildings in Croatia.

“The key was to have the transfer plate on the first floor to accept the upper walls and columns as vertical loads.”

To deliver all of these three different functions in one building, we have found that the construction of a transfer plate is an effective and practical solution. At IVE Mikaca, the transfer plate is a slab consisting of shallow beams (2,400 x 700mm) in both directions and a slab thickness of 220mm between them. Seismic resistance was achieved with two staircase and lift cores and façade frames made of a rigid beams and columns – the Vierendeel system.

The ground and first floor slabs were built with larger spans of up to 12m and then the upper residential floors were constructed above them. The key was to have the transfer plate on the first floor to accept the upper walls and columns as vertical loads. So, the first floor acts like a foundation slab for the upper floors. The tendons in the transfer plate were stressed in several phases – these followed construction of each upper floor.



BARANGAROO DEVELOPMENT, SYDNEY, AUSTRALIA

Progress report from city's largest construction project

MASSIVE WATERFRONT REGENERATION

It was back in 2011 that we constructed the first building in this way – in Varaždin, Croatia. Since then, we have delivered four similar building projects for the same customer. Around 20t of BBR VT CONA CMM tendons were embedded in each building – each of which feature floor areas of 800m².

There are many benefits of this kind of construction. It is possible to have bearing walls outside of the apartments, giving future potential buyers or clients freedom to arrange the rooms as they wish. Also, the underground parking garages have fewer walls and columns, so maneuvering vehicles is much easier and sight-lines clearer.

After these four projects in Varaždin, a new investor has decided to build the first building with a transfer plate in Cakovec – not far from Varaždin. This project is still in progress and, here, we decided to go a step further and prestress a foundation plate to reduce slab thickness. ●

- 1 The BBR Adria team is seen here working on the post-tensioned foundation slab for a new building. After recognizing the benefits of post-tensioned transfer plates in nearby Varaždin, the new investor decided to commission the first building in Cakovec to feature a transfer plate.
- 2 The Ive Mikaca scheme is the latest in a series of multifunctional buildings constructed with a transfer plate.

TEAM & TECHNOLOGY

Developer – Marlex Invest d.o.o.

Designers – Miljenko Kovač, Predrag Presečki (PT slabs)

Main contractor – Megrad 3B d.o.o.

Technology – BBR VT CONA CMM monostrand

BBR Network Member – BBR Adria d.o.o. (Croatia)

Barangaroo is the largest construction project in Sydney since the turn of the millennium – a 22-hectare harbor-front urban renewal project that involves the complete transformation of the western edge of Sydney's CBD. The site involves three areas – Barangaroo Reserve, Central Barangaroo and Barangaroo South. When finished, the former container port will be transformed into a mix of office and residential towers, plus recreational spaces such as public waterfront walks and parks.

SRG has worked alongside Lendlease, the developer and main contractor for Barangaroo South and the main contractor for the Barangaroo Reserve, as the five year program of works has progressed. SRG's role has focused on the post-tensioning works, including three multi-storey towers and additional slabs, entailing close to 2,500t of 15.2mm steel prestressing strand. In the last year, SRG has completed substantial post-tensioning works on the commercial office towers and apartments at Barangaroo South, including shop

drawing, installation, stressing and grouting. SRG also undertook post-tensioning works for the Napoleon Bridge that spans across Sussex Street. SRG's civil engineering team also completed the stressing of beams used for the Barangaroo Reserve cultural space. This project involved the construction of a land bridge – supporting a park, complete with bicycle paths, walking tracks, retaining walls, water mains, trees and grassed areas over the top of a large 17m high 18,000m² open floor space. ●

TEAM & TECHNOLOGY

Developer – Lendlease (Barangaroo South), Barangaroo Delivery Authority (Headland Park), Transport for NSW (Wynard Walk)

Main contractor – Lendlease (Barangaroo South & Headland Park), Thiess Contractors (Wynard Walk)

Subcontractor – Ward Civil (Wynard Walk), Baulderstone (Headland Park)

Technology – BBR CONA flat, MRR range, PT bar

BBR Network Member – SRG Limited (Australia)



POST-TENSIONED FLOORS, NEW ZEALAND

350,000m² of PT floors delivered in 14-year relationship with international commercial property specialist

LONG-TERM PARTNERSHIP FOR QUALITY

Some might call it a match made in heaven, but the BBR Network's more pragmatically minded post-tensioning specialists in New Zealand simply call it a successful partnership. There's certainly proof in the numbers – in a 14-year long working relationship, BBR Contech has designed and installed BBR post-tensioning for 46 floors for commercial property specialist Goodman. Together, they have created an impressive total of 350,000m² of post-tensioned floors – equating to around 50 rugby pitches – this is a significant achievement in anyone's terms.



The post-tensioned floors, ranging in size from 2,000m² to 30,000m², have been installed in five business parks in Auckland, all owned and managed by Goodman Property Trust – an NZX listed entity which has a NZ\$2.2 billion property portfolio and around a million square meters of rentable space in business parks, industrial estates, office parks and warehouse and distribution centers.

Goodman's success reflects its focus on owning, managing and developing only premium-quality properties in New Zealand's main distribution centers of Auckland and Christchurch. All of its assets offer modern, highly functional spaces for a range of customer uses and many provide on-site facilities, such as gyms, cafés, banks and childcare services. Located close to major arterial routes and city centers, they have attracted around 250 customers – including global brands such as DHL, BMW, Toll and Woolworths – and are delivering enviably high occupancy and retention rates. A number have also won awards for their architectural merit, environmental sustainability and investment performance.



2

“Post-tensioned flooring is definitely my first choice where it’s an appropriate option – and I’d certainly recommend it to others.”

Peter Yendell, Infrastructure Manager, Goodman



3

Insistence on PT floors

Goodman has specified PT floors for about half of its total property portfolio. According to Peter Yendell, Goodman’s Infrastructure Manager, the company’s decision to use the technique reflects its commitment to long-term investments and insistence on quality at every stage of the construction process. “We operate in a competitive market where our ability to attract and retain high-caliber customers depends on the quality of our properties,” he says. “We strongly believe in building well and managing our assets

effectively throughout their lifecycles, as this ultimately improves their long-term environmental and financial performance. PT floors offer a number of advantages over the alternatives. For a start, they’re stronger so they can handle heavier loads, and they have a total absence of joints, which reduces the risk of cracking and avoids joint degradation. They also have a more attractive appearance, are easier to maintain and have longer lifespans – and they provide us with flexibility for fit-outs, which is vital in meeting our customers’ specific operational needs.”

- 1 BBR Contech’s regular customer, Goodman, owns, manages and develops premium quality properties for a range of clients including global brands such as BMW.
- 2 The award winning Ford Building in the Highbrook Business Park incorporates a post-tensioned concrete floor system providing largely column-free interior space with minimal structural depth.
- 3 At East Tamaki’s Highbrook Business Park, BBR Contech installed a 30,000m² slab for Goodman tenant DHL Excel.
- 4 Kmart’s principal distribution hub on the M20 estate in Manukau City where, since 2008, BBR Contech’s post-tensioned floors have provided effective solutions for the construction of 11 separate facilities.
- 5 Flitway – one of New Zealand’s largest logistics providers – has its Auckland branch office at Westney Industry Park where BBR Contech has installed post-tensioned floors for 10 of the park’s buildings.

14 years of performance

The BBR Contech-Goodman partnership began in 2002 at The Gate, a premium industrial estate in Penrose. Working with head contractor Haydn and Rollett, Allied Concrete and concrete floor specialists Conslab, the BBR Contech team designed and installed eight PT slabs in four years, with floor areas ranging from 2,000m² to 10,000m² and totaling 36,000m². In the 10 years since then, the team has applied its post-tensioning expertise to:

- Goodman’s flagship property, the world-class Highbrook Business Park, which is situated on 150 hectares of landscaped grounds and parkland in East Tamaki. Between 2006 and 2014 BBR Contech installed the PT for 21 floors covering a total 172,700m² – the largest being a 30,000m² slab in 2007 for Goodman tenant DHL Exel. The estate continues to be actively developed, with a further 42.6 hectares of land still available.
- M20 Business Park, which offers more than 100,000m² of warehouse and office space in the heart of Manukau City. BBR Contech installed PT for 8,000m² of flooring for tenant James Halstead Flooring in 2008 – and has since installed a further 43,000m² in 10 more buildings, the most recent in 2015. At the M20 estate, post-tensioned floors have been an effective way of designing and building over a combination of hard and soft pile raft systems, allowing the elimination of pile caps and ground beams.
- Savill Link, a warehouse estate for both medium and heavy industrial uses, in which BBR Contech installed PT for 26,400m² of flooring – one slab of 6,400m² and the other 20,000m² – in 2011 and 2013.
- Westney Industry Park, a premium industrial space located next to Auckland International Airport, whose occupants include Cotton On, DSL, DHL, Fliway, Linfox Logistics and Supply Chain Solutions. BBR Contech worked on the site between 2006 and 2008, installing PT for 57,700m² of flooring in 10 of the park’s 16 buildings.

Asked why he keeps coming back to BBR Contech, Peter says: “As a company that specializes in designing and installing post-tensioned floors, they offer very sound engineering solutions that meet our customers’ needs. They work in close partnership with concrete floor specialist Conslab and our numerous building teams to consistently deliver a quality product that meets our budget.”



4



5

International perspective

Goodman’s commitment to excellence and its extensive customer base expose it to trends and developments on a global scale. Peter says that New Zealand appears to use post-tensioned flooring to a far greater degree than do Goodman’s counterparts around the world.

“This may be because of customer specifications, personal preferences and engineering and cost considerations, but it still surprises me,” he says. “Post-tensioned flooring is definitely my first choice where it’s an appropriate option – and I’d certainly recommend it to others.” ●

TEAM & TECHNOLOGY

Owner – Goodman Property Trust
Technology – BBR CONA flat
BBR Network Member – BBR Contech (New Zealand)



1

GUOCO TOWER, SINGAPORE

Progress report on high rise PT construction project

REACHING FOR THE SKIES

Guoco Tower located on top of the Tanjong Pagar MRT Station, at the junction of Choo Guan Street and Peck Seah Street will be Singapore's tallest building when completed. Singapore-based BBR Construction Systems provide a photographic progress report of work on this spectacular project.

The Tanjong Pagar Development is a mixed scheme comprising a six storey podium and two towers of 20 and 64 storeys respectively. The 64-storey tower will house 38 floors of Grade A office space and 26 floors of residential apartments, while the 20-storey tower will be a 200-room hotel. The structural system used for the tower consists of one way post-tensioned beams with deep deck system slabs.

The post-tensioned beams are 700mm deep and vary in width from 1,000mm to 3,000mm. The deep deck system comprises 1.2mm thick steel sheets formed into tapered ribs of 250mm deep and 100-190mm wide at 600mm spacing, with a 150 to 180mm thick structural topping. There is a seven meter maximum clear span between beams. The slab was analyzed and checked as a plate to mobilize the torsional stiffness of the beams and columns. ●

- 1 The Guoco Tower takes shape as part of Singapore's Tanjong Pagar mixed development.
- 2 View of a typical deep deck slab, at the Guoco Tower site, where there is a maximum clear span of seven meters between beams.

TEAM & TECHNOLOGY

Developer – Guocoland Limited

Architect – Skidmore, Owings & Merrill LLP (SOM)

C&S consultant – Arup (Singapore) Pte. Ltd

Main contractor – Samsung C&T Corporation

Technology – BBR CONA internal

BBR Network Member – BBR Construction Systems Pte. Ltd. (Singapore)



2

Q22, WARSAW, POLAND

PT slabs for high rise building

CHANGING THE WARSAW SKYLINE

For the last two years, BBR Polska has been delivering specialist post-tensioning technology and know-how for the construction of one of the tallest high-rise buildings in Warsaw. Bartosz Łukijaniuk, BBR Polska's Design Team & Works Manager, tells of the company's role in the realization of the 155m high office building, known as Q22.

The building is being constructed on the site of a former hotel which was demolished to make way for new offices. With an address in the heart of Warsaw's business district and vision of providing first class office space, this has been an extremely prestigious building project – right from the design stage, through project management and site supervision, onto the execution of the various elements. It would be no surprise, therefore, to learn that only top class specialists were invited to join the project.

Building layout

The building has five underground levels and 42 storeys above ground, 39 of which are post-tensioned. The first 16 above ground levels form an 84m x 30m podium from which the 26-storey tower – pentagonal on plan, 55 x 30m – begins to rise. The total slab area is around 58,800m² and the whole building will offer some 50,000m² of office space and also house many amenities including restaurants, fitness area and lockers for cyclists.



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Post-tensioning

There were uneven spans between columns and walls, thus some areas of the slabs were heavily post-tensioned, some areas only have tendons in column strips and some have no post-tensioning at all. We used the BBR VT CONA CMF system for all the slabs. In addition, a few edge beams were post-tensioned with 1206 BBR VT CONA CMI tendons – due to long spans and deflection limitations.

The slabs were designed, by Buro Happold engineers, to be post-tensioned with flat bonded tendons. Our design scope was to deliver the detailed tendon layout. Close cooperation between the design parties – BBR Polska, gp-projekt and Buro Happold – resulted in an excellent performance on site. At this point, it is also important to mention that the detailed designs for post-tensioning and mild reinforcement were coordinated along with other detailed elements – such as façade fixing design, design of the mounting for the temporary wind shields (structures needed during the lifting process) and other temporary and permanent structural and finishing items.

Construction phases & schedule

Construction of the building was divided into two phases. Firstly, the tower part was constructed, then secondly, when the tower reached level 20, work on the podium section began.

The construction schedule was extremely tight. Each whole level – including walls, columns and slabs – was constructed in five days.

Such a challenging time schedule fostered good cooperation between all teams involved in the execution process. The very detailed planning of the construction sequence, carried out by the highly skilled and experienced frame contractor engineers, was extremely important.

Despite the challenges, the construction process went smoothly.

The realization of our part of the project took about ten months. During this time we installed 153t of stressing steel in almost 2,000 tendons – and for the grouting, we used almost 55t of cement.

For the BBR Polska team, it was a fantastic experience to work on such a project and a great opportunity to demonstrate the advantages that PT technology brings to the construction of high-rise buildings. Working in the confined space of a single slab pour, together with mild reinforcement fixers and under time pressure where the complete installation of tendons for one slab pour took only one day, was a challenge which we overcame with great success. We hope that our experience, in terms of both execution and design, will be called upon in the future to benefit other high-rise buildings that will be constructed in Poland. ●

“For the BBR Polska team, it was a fantastic experience to work on such a project and a great opportunity to demonstrate the advantages that PT technology brings to the construction of high-rise buildings.”

1 The extremely prestigious Q22 project will provide first class office space in Warsaw's business district.

2 With very tight schedules, the project fostered good cooperation by all teams involved. Photograph courtesy of gp-projekt sp. z o.o.

3 Inspection of one of the completed levels – each of which – including walls, columns and slabs – was constructed in five days. Photography courtesy of Michal Stefanowicz.

TEAM & TECHNOLOGY

Developer & general contractor – Echo Investment S.A.

Architect – Kurylowicz & Associates Sp. z o.o.

Structural design (inc PT) – Buro Happold Polska Sp z o.o.

PT detailed design – gp-projekt sp. z o.o. & BBR Polska Sp. z o.o.

Frame contractor – Modzelewski & Rodek Sp. z o.o.

Project management & supervision – Gleeds Polska Sp. z o.o.

Technology – BBR VT CONA CMF flat, BBR VT CONA CMI internal

BBR Network Member – BBR Polska Sp. z o.o. (Poland)

RZESZÓW BRIDGE, RZESZÓW, POLAND

Speedy stay cable installation

VOYAGE OF DISCOVERY

By the time Kate Janikowska, Press Officer of BBR Polska, arrived at the Rzeszów Bridge site with her camera, the team had already installed the last stay cable and the official opening of the bridge was rapidly approaching. She thought that there would be nothing new to photograph, but her visit soon became an exciting voyage of discovery.



It was relatively late when I reached the construction site – late in the day and towards the end of the construction phase, the last stay cable had already been installed. There was a certain stillness about the place and the site looked quiet compared to the hectic earlier days of the project.

This was a shock, so I checked the date. Had the appointment really been made for today? The site was definitely the right one – this was the only thing I could be sure of, as I had spotted Rzeszów's massive new landmark from way off in the distance.

The security guard explained that most teams had already left the site and would be back tomorrow, only the BBR team was still there – they would work until at least 7pm, but they were all inside the pylon.

After texting my hosts and a short wait at the barrier, BBR Polska's Chief Engineer 'Master Builder' Tomasz Borsz appeared, waving and hurrying towards me. On hearing my concerns about the apparent lack of anything significant being underway, Tomasz set out to prove just how exciting the project still was – even at this advanced stage so close to completion. ➤







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Significant moment

As we stood beside the new bridge deck, Tomasz pointed to the gap between the deck and its temporary supports. The bridge was now suspended by the stay cables. This meant that the 64 BBR HiAm CONA stay cables were fully installed and doing their job as intended.

Cable-stayed solution

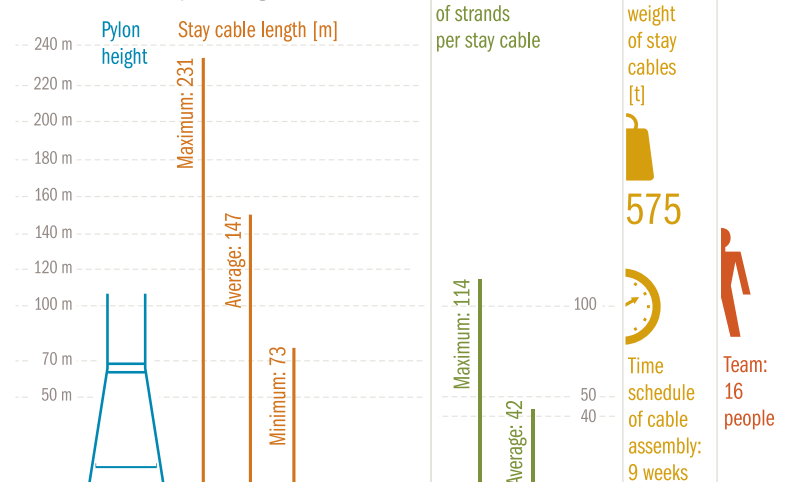
It really was 30 years ago that the northern inner by-pass of the city had first been envisaged, as a response to predictions that Rzeszów city center would soon need relief from traffic congestion. It was planned that West-East transit traffic was to be transferred to the new bypass. Rzeszów is the biggest city in south east Poland and, since 1999, has been the capital of Podkarpackie Voivodeship. At first, the large size of the bridge seemed surprising, as was the decision to erect a cable-stayed structure over a watercourse only several meters wide – but the bridge spans more than just the Wisłok river. One of the design requirements was to reduce the number of piers, both in the river and on the flood plain, as the area is protected under the Natura 2000 environmental scheme. Next, there is a water reservoir adjacent to the river,

which belongs to Rzeszów Power Plant – and it also had to be crossed without using piers. Thus a cable-stayed bridge, with a 107.2m high pylon, was considered the perfect solution.

For all these reasons, Rzeszów now has a landmark bridge – and the contractor has had the opportunity to design and construct a cable-stayed structure, a solution normally only chosen for crossing the major Vistula or Odra rivers, as Poland has no dramatic topographical features.

- 1 BBR Polska’s Chief Engineer Tomasz Borsz hosted many visits to the site, as well as leading the stay cable installation team.
- 2 Rzeszów Bridge at night, just after the official opening ceremony. Photograph courtesy of Porr Polska Infrastructure SA / press material.
- 3 Late in the afternoon, the Rzeszów Bridge site looked still and silent, as most of the BBR Polska team were at work on top of or inside the pylon.
- 4 A significant moment – the stay cables were now carrying the weight of the bridge.
- 5 The completed bridge – pile heads of the temporary supports are still visible in the river beneath and awaiting dismantling and the concrete base rings filling with underwater concrete by divers. Photograph courtesy of Porr Polska Infrastructure SA / press material.

Rzeszów Cable-Stayed Bridge – Overview





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“The 64 stay cables, arranged in four sets of 16 cables each, spread from the pylon in two planes like a fan.”

Fancy footwork

The new bridge has five spans (30 + 30 + 30 + 150 + 240m). There are six piers – two of which are abutments, three others tie-down the back span and the last one is the pylon. The structure was incrementally launched, so there were 22 temporary supports – 11 on each side of the bridge – and these required some really fancy footwork.

The bottom of the power plant water reservoir is covered with an HDPE liner which had to be cut each time a pile was to be driven, thus avoiding uncontrolled tears in the liner.

So, for each pile, a diver would jump into the water, cut the liner, then the pile was driven to the exact co-ordinates and covered with a prefabricated collar made of HDPE lining material. Next, the collar had to be pressed with a concrete ring and filled with aggregate. When the temporary supports are dismantled, the piles will be cut and the rings will be filled with concrete poured under water.

Exciting trip upwards

Next, Tomasz escorted me to the top of the pylon so that I could examine more closely one of the places in which our team had been working.

The pylon, shaped like an inverted tuning fork, is essentially a reinforced concrete structure with a box cross-section, strengthened with steel inserts located at the upper stay cable anchorages. The 64 stay cables, arranged in four sets of 16 cables each, spread from the pylon in two planes like a fan.

The live end anchorages in the pylon are spaced every 1.7m, while the passive anchorages are at 12m intervals in the deck between the carriageway and the lanes for pedestrians and cyclists. ►



5

View from the top

The view from the top of the pylon was simply stunning. However, the view down inside the pylon was even more impressive. There were around five stepladders leading downwards and I could just make out the high visibility safety vests and helmets of the BBR team working way below us. The reason that the site looked empty is that most members of the BBR team were inside the pylon and therefore not visible. It was hard to imagine that, just a few months before, steel fixers and concrete placers were working above the heads of the BBR team.

Also, some of the crew were working inside the deck where they were injecting the anchorages with resin and installing end protection caps – both procedures are for corrosion protection. This site, like many similar projects, has two extreme environmental conditions – the wind at the top is fearsome while inside the deck, it is incredibly hot.

Progress has been really breathtaking – the whole project, along with the access roads, was completed in less than two years. Stay cable installation was carried out at a cracking pace by the 16-man BBR Polska team who finished their work in just nine weeks.

The safe, comprehensive and effective scheduling of numerous phases, trades and workers has been an outstanding feature of this project. Now having an

appreciation of the work scope and fast program, it is easy to understand why Tomasz Borsz believes that Bilfinger Infrastructure should receive a special award for their excellent site organization. "It may look simple," commented Zygmunt Dereszkiwicz, Bilfinger Infrastructure's bridge works manager, "but actually, the achievement is a direct result of BBR Polska's experience and ability to cooperate in extreme conditions as each structure is different." "They are a perfectly organized team," said Konrad Przymorski, also from Bilfinger Infrastructure, "but it's really great that the cables have now been installed because when they were laid out on the deck you couldn't walk or drive on it," he added with a smile.

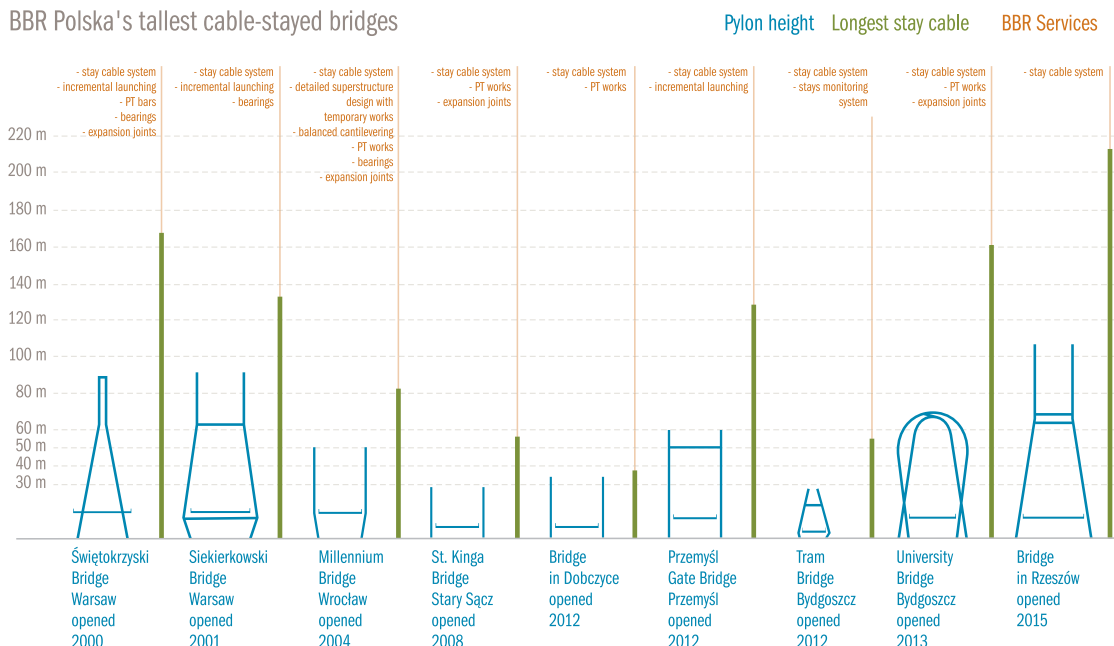
Experience is certainly an important factor. Our team has applied BBR stay cable technology to several dozen structures – most frequently between 30 and 120m high, all with long cables and a large number of strands. While the stay cables in Bydgoszcz, our previous stay cable project, have a significant cross-section – from 72 to 109 strands – the largest stays in Rzeszów have 114 strands. On closer inspection of the BBR HiAm CONA stay cable pipes – which feature helical ribs as a primary countermeasure against cable vibration – I noticed something interesting. There was space to install a damping device. The damper housing is located between the bottom

of the anchor zone – a steel pipe to carry the cable – and an anti-vandal pipe. Having never seen it before, I consulted Tomasz Borsz who explained that measurements would be taken during a structural monitoring phase. The results of the monitoring will form the basis for establishing damping parameters and then the most optimal BBR damping device will be selected. It is currently envisaged that BBR Viscous Dampers will be installed in half of the stay cables. We will await with great interest to see what decisions are made.



6

BBR Polska's tallest cable-stayed bridges





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Special visitors

Once inside the site office, I was shown some photographs – among them, pictures of Messrs Voon, King and Seven from BBR Malaysia ... on site, here in Rzeszów. Tomasz described how stay cable specialists are always curious about the approach to cable installation techniques taken by teams worldwide. While it may seem that installation is carried out in exactly the same way for every project, in fact no two structures are identical. There had been other guests too. Dr Behzad Manshadi from BBR VT International Ltd came to observe the installation and performance of the BBR CONA HiAm system. Also, Günter Damoser of KB Vorspann-Technik GmbH had also been on site – several years earlier, he had hosted Tomasz at his Sava Bridge construction site in Belgrade and this was a return invitation. The two engineers had a brainstorming session about the most effective technological solutions on their respective projects.

Trade secrets

My musings were suddenly interrupted when I hit my leg on something hard under the table. It was a box and just as I was about to look inside, Tomasz warned me “Don’t touch! That’s the Chief Engineer’s Stay Cable Tool Box.” Then, he relaxed a little: “Well, OK you can have a look, but no photographs – inside are our specialist tools.” In the box, I saw some tiny wedges – Tomasz would not let me take one – and something that looked like pliers. “That’s enough,” said Tomasz abruptly, “I’m taking the box with me.” Thus, my exploration was over when Tomasz left the office with his precious box – and, incidentally, my coffee as well. It was clearly time for me to leave and reflect on how the devil is always in the detail. This project has not just been about the huge stay cables, kilometers of strand and tons of steel, but also about taking care of the small details which, to the casual observer, are hard to see in the shadow of the imposing 107m high pylon. ●

- 6 The stunning view downwards from the top of the pylon.
- 7 Right to left: Messrs Voon, King and Seven from BBR Malaysia taking a well-earned break after helping the BBR Polska team with cable installation during their visit to the Rzeszów Bridge site.
- 8 The BBR Polska team assembles at the top of the pylon, ready to go home at the end of the day.

TEAM & TECHNOLOGY

Owner – Gmina Miasto Rzeszów
Architect – Promost Consulting
Designer – Mosty Gdańsk
Main contractor – Porr Polska Infrastructure (formerly Bilfinger Infrastructure)
Technology – BBR HiAm CONA stay
BBR Network Member – BBR Polska Sp. z o.o. (Poland)

ELIZABETH QUAY PEDESTRIAN BRIDGE, PERTH, AUSTRALIA

Hanger installation & heavy lifting

ARCHITECTURAL HIGHLIGHT ON THE WATERFRONT

The BBR Network Member in Australia, SRG, has played a crucial role in the construction of the iconic centerpiece feature, of Perth's exciting new Elizabeth Quay development – a double arch pedestrian and cyclist bridge. Richard Blair of SRG provides an overview of the project.



Elizabeth Quay is a major Western Australian development project currently under construction in Perth's central business district being delivered by the State Government. Located on the north shore of the Swan River, the Elizabeth Quay development is a A\$2.6 billion project designed to revitalize Perth and embrace one of city's best natural assets. The project is a significant development for the city and will feature a stunning inlet connected by 1.5km of continuous boardwalks and promenades, delivering great public leisure spaces, new hotel and short stay accommodation and contemporary inner city living opportunities.

Landmark bridge

Working together with Decmil and Hawkins Civil under the DASSH Joint-Venture, we were contracted by Leighton Broad to bring the unique double arch bridge design to life, through technical engineering and construction work.

The 20m high double arch, cable-stayed suspension bridge is the first of its kind in Perth. In line with Australia's many renowned port and waterfront icons, the Elizabeth Quay bridge will create a striking architectural feature for the future precinct and the city, connecting the ferry terminal and Williams Landing to the new Island.

Lifting experience

SRG's expertise in innovative structural engineering and detailed civil infrastructure has been integral to bringing the ambitious architectural design to reality. The bridge has been under construction since early 2014 and, last year, the massive 86t arches were constructed and lifted into place. Due to the size and shape of the arches, lifting and erecting each structure was no easy feat, the boom radius did not allow the arch lift to be completed in a single operation. A 275t crawler crane and hydraulically adjustable intermediate prop were utilized to support the arch at a lower level before tracking the crane back to complete the lift. This complex process was made possible through the expertise and hard work of a number of skilled structural and civil engineers, structural steel fabricators and site operatives.

Hangers

Our extensive experience with cable-stayed structures saw the in-house design and operation of the bespoke cable stressing assemblies, with a pair of 30t center hole jacks applying the loads to enable pin engagement. A total of 16 hangers tie the arches and bridge deck together. Each span comprises a mix of 25, 30 and 35mm diameter hangers in varying lengths to best suit the load case at each location. Having completed the main structural elements of the bridge, the next steps in the project will see the deck and architectural finishes installed ahead of the opening to the public. For SRG, it has been a privilege to be involved in this significant development for the city of Perth and to deliver this important component of the project for Leighton Broad. ●

1 One of the two massive 86t arches being lifted into place for Perth's new double arch cable-stayed suspension bridge.

TEAM & TECHNOLOGY

Owner – Metropolitan Redevelopment Authority

Architect – ARUP

Designer – ARUP

Main contractor – Leighton Broad

Technology – Heavy lifting, hangers

BBR Network Member – SRG Limited (Australia)

HENDON PARK FOOTBRIDGE, AUCKLAND, NEW ZEALAND

PT expertise for pedestrian and cycling bridge

STRIKING SIMPLICITY

If there were a competition for the most beautiful bridge in New Zealand, the list of contenders would be a long one – but the latest kid on the block could very well steal every prize going.

The team at BBR Contech are thrilled to be part of the 320m-long Hendon Park Footbridge project, a key element in the largest and most ambitious road scheme ever undertaken in New Zealand. Called the Waterview Connection, the NZ Transport Agency's NZ\$1.4 billion project will provide the final link in a 48km motorway ring route around Auckland city – easing congestion on state highways elsewhere in the network, enabling better connections for motorists and improving links to the city's northern and southern neighbors.

The simple, elegant and utterly beautiful pedestrian and cycling bridge was designed by Beca and Warren & Mahoney Architects and is being built by the Well-Connected Alliance. Its ten span concrete deck with a central 80m span over SH-20, finished in

arctic white, will curve through space, connecting to a sculpted arch via a complex cable configuration that forms a hyperbolic paraboloid.

BBR Contech has supplied PT bars for two massive concrete abutments that will take the load of the main arch bridge. It has also supplied all 39 steel hanger bars – helping to create a bridge that will be loved, lingered on and talked about for many years to come. ●

TEAM & TECHNOLOGY

Developer – NZ Transport Agency

Architect – Warren & Mahoney

Designer – Beca

Main contractor – Well-Connected Alliance

Technology – PT bars, steel hangers

BBR Network Member – BBR Contech (New Zealand)



ONSHOW WATER TANKS, WESTERN AUSTRALIA

Post-tensioned precast panels

INNOVATIVE WATER TANK SOLUTION



BBR Network Member SRG recently completed a major project for Western Australia's Water Corporation to construct two 5ML water storage tanks and associated pipelines, in the town of Onslow, 1,400km north of Perth, on the Pilbara coast.

The recent development of several large gas field projects in the vicinity of Onslow was driving town growth and increased water demand. The existing town water supply infrastructure had reached its capacity and two new water storage tanks were needed to ensure the township has sufficient water to meet its current and future needs.

Innovative bid

A tank design and construct contract was issued with the option to submit bids for the construction of either steel or concrete tanks. SRG's project team submitted a successful bid to construct concrete tanks based on an innovative post-tensioned method. The advantage of using concrete is that it requires less ongoing maintenance than steel and lasts up to 100 years. SRG developed pioneering precast panels, post-tensioned in two directions, to overcome any potential cracking in the precast concrete. The panels were cast in Perth and then transported to site where they were stitched together using a customized concrete mix that responded to the harsh environmental conditions. This process ensures the concrete is kept in compression in both directions. Should a micro-crack occur in the concrete, the panels have been designed to self-seal – effectively closing the crack.

First in Australia

The contract also required that the tanks, which weigh 6,000t, be constructed on sandy ground. Because of the potential for ground settlement, under the weight of the tanks, each tank site was pre-loaded with fill material to self-compact prior to the tanks being constructed. Specialist settlement sensors were obtained from the US for this part of the project, which was the first time this technology had been used in Australia. SRG was the principal contractor for this project and responsible for the full management of the design, construction, testing and commissioning of the two water tanks. This also involved managing contractors and consultants who were also on site.

This contract was, however, not without its environmental challenges. Over the course of the project there were cyclones and floods. Nevertheless, the team was able to overcome these weather events to deliver a successful outcome on-time for the client – all the while working in the relentlessly extreme heat of the Pilbara region. ●



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- 1 SRG developed pioneering precast panels which were cast in Perth and transported to site for erection.
- 2 The 6,000t tanks had to be constructed on sandy ground, so each tank site was pre-loaded with fill to self-compact and specialist sensors were used for the first time in Australia to monitor any potential settlement.
- 3 Members of SRG’s senior management visit site to review the completed project. Left to right: David Macgeorge (Managing Director), Radwan Hamoshi (Project Manager), Kim Boyd (Regional Manager Construction).

TEAM & TECHNOLOGY

Client – Water Corporation Western Australia
Main contractor – SRG Ltd
Technology – Precast PT panels
BBR Network Member – SRG Ltd (Australia)

“I am writing to thank you and the SRG team for the great work undertaken in the design and construction of the two 5 ML water storage tanks and associated pipelines at Onslow, WA. This project has been challenging given its remote location and climate. However, these challenges have been overcome through detailed planning and organization ... SRG has consistently demonstrated its commitment to managing the existing environmental conditions and maintaining a safe worksite during the entire project.”

Scott Shand, Project Director, Regional Water Conveyance



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BID-BOSUT PUMPING STATION, VINKOVCI, CROATIA

Permanent & temporary ground anchors

ANCHORING FOR AGRICULTURE

Several droughts during earlier years of the 21st century have endangered the stability of agricultural production in Croatia. Now, as part of a national project to improve irrigation and land and water management, a new pumping station is under construction near Vinkovci, in the Bid-Bosut area – with some expert help from local BBR Network Member, BBR Adria. Goran Tomišić outlines the project which involves the region’s largest ground anchoring operation in the last five years.

The new 16.4 x 20.5m pumping station will provide water for irrigation through the controlled release of water from the Sava River to raise low water levels in the amelioration channel. The station, which is located in the amelioration channel, will have a total pumping capacity of 10m³/s – using four pumps with a flow rate of 2.5m³/s each – and be capable of pumping to a height of four meters. The 16.4 x 8.8m section of the project dealing with drainage takes the form of cascading pools of differing heights. These allow water to overflow towards the amelioration channel, leaving sediment behind while slowing down water flow and having the environmentally beneficial effect of increasing oxygen levels in the water as it mixes with the air

Reinforced walls

Construction of the pumping station began with reinforced concrete retaining walls. The 11m deep construction pit is rectangular with an area of just over 805m². It has been designed and constructed with reinforced concrete retaining walls featuring four rows of ground anchors. The walls will also form part of the pumping station itself. The function of the retaining walls is three-fold – to preserve the stability of the vertical excavation of the construction pit, prevent the hydraulic fracturing of the soil inside the pit and, finally, as a part of the ongoing construction of the pumping station. To support these functional requirements, the retaining walls have been designed so that the four meter entrances are in an area of low permeability silty clay which prevents water seeping through the bottom of the excavation.

- 1 The first and second rows of anchors were installed at an angle of 6° and the third and fourth line at an angle of 15° – spacing was at 2.5m.
- 2 Aerial view of the site, showing amelioration channel, with construction of the pumping station on its alignment and River Sava in the background.

TEAM & TECHNOLOGY

Owner – Hrvatske vode
Main contractor – Eurco d.d.
Designer – Institut IGH d.d
Technology – BBR VT CONA CMG ground
BBR Network Member – BBR Adria d.o.o. (Croatia)



HATAITAI BUS TUNNEL, WELLINGTON, NEW ZEALAND

Ground anchoring and grouting

STRENGTH, RESILIENCE & PERFORMANCE

A high-profile project in New Zealand's capital city is harnessing BBR Contech's extensive experience in ground anchoring and grouting.

The Hataitai Bus Tunnel opened in 1907, providing much-needed access for trams running between Wellington city and the eastern suburbs of Kilbirnie and Hataitai. In 1963, electric trolley buses replaced the trams and, today, buses continue to travel the tunnel's 365m length, making about 2,400 journeys a week.

A structural assessment in 2014 revealed that, while the tunnel was likely to withstand a reasonably large earthquake, the adjacent hillside and old tunnel entrances could come down and block the route.

This was the cue for BBR Contech – and a six-month project starting in November 2014. Technically demanding owing to the site itself and poor ground conditions in places, it included strengthening the tunnel portals by excavating for and constructing new vertical buttresses and wing extensions on both sides of each entrance – and attaching a new reinforced-concrete ground beam across the top of each portal.

To achieve this, the team installed a total of five full-scale proof anchors and 30 double-corrosion-protected anchors using 32mm and 40mm PT bars. It was a complex process that included water-tests for the drilled anchor boreholes, preliminary grouting and re-drilling, full-scale on-site suitability and pull-out tests – and repeated cycles of high-pressure post-grouting for all the ground anchors. Comprehensive project and noise management plans ensured minimal disruption for bus schedules, passengers, local residents and businesses. ●

Ground anchors

The BBR VT CONA CMG ground anchors comprise four strands, each with a cross-sectional area of 150mm² and a characteristic tensile strength of 1,860MPa. The anchors are founded in layers of sand and gravel of medium or thick compaction – and stressed to 400kN.

The first and second rows of anchors were installed at an angle of 6° and the third and fourth line at an angle of 15°, they are spaced 2.5m apart. We installed a total of 5,526m of temporary anchors and 2,511m of permanent anchors.

Further stages

After the excavation of the foundation pit, the base plate and inner walls of the pumping station will then be executed, along with the floodgates. To achieve a monolithic effect for the structure, a connection needs to be created between the structure and the inner structure of the retaining walls. This will be accomplished by installing fasteners (dowels) in the retaining walls. The geotechnical anchors installed in the northern and southern retaining walls are permanent corrosion protected anchors, while those in the western and eastern walls are temporary and serve only while the retaining walls are needed to protect the construction pit. We have installed a total of 83 permanent and 234 temporary anchors for the project. ●

TEAM & TECHNOLOGY

Owner – Wellington City Council
Designer – Opus International Consultants
Technology – PT bar ground anchor
BBR Network Member – BBR Contech (New Zealand)





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SWISS PT INNOVATION

Non-standard applications meet customer needs

LIMITLESS APPLICATIONS FOR POST-TENSIONING

- 1 Railway Bridge Lotto 781 in Bellinzona. Two short BBRV tendons were installed as seismic protection.
- 2 Tendons passing from foundation into the pier of Railway Bridge Lotto 781.
- 3 Railway Bridge Lotto 782 in Bellinzona – two short BBRV tendons fix the bridge deck to the pier.
- 4 Post-tensioned steel girder for Terminal 2 at Zurich Airport. The dead end anchorage can be seen on the left, with the deviation saddle in the center.
- 5 The House of Natural Resources, ETH Zurich provides offices – and also serves as a pilot installation for studying the structural performance of wood from deciduous trees, combined with post-tensioning.
- 6 The House of Natural Resources, ETH Zurich – the laminated beams of each span are connected to the hardwood columns only by one post-tensioning tendon which has been pushed through the central cavity of the beams – thus they are flexurally rigid.

BBR technology has always proved flexible and its innovative use for non-standard applications to meet customer requirements is embraced the world over. Jürg Däniker of Swiss-based BBR Network Member, Stahlton AG, reports on several projects from the past year where his company has supported engineers in devising and implementing innovative yet practical solutions to construction challenges using BBR post-tensioning systems.

1 Seismic protection for railway viaduct

Near Bellinzona in Switzerland, 15 piers of a 1,010m long railway viaduct had to be stabilized by anchoring into the foundation blocks. The requirements for this project were:

- tendon length – approx. 3.5m
- tendon force – between 5,270 and 8,933kN MBL
- tendon must permit for adjustment due to settlement of -50/+140mm
- angular rotation of +/-1.4 degree
- tendon must be electrically isolated

On either side of the central guide bearing, Stahlton proposed the use of BBRV wire tendons with 82, 102 or 139 galvanized 7mm diameter wires encapsulated in thick walled PE ducts filled with a flexible grout to protect against corrosion.



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TEAM & TECHNOLOGY

- 1** **Owner** – Swiss Federal Railway represented by AlpTransit San Gottardo SA
Main contractor – Consorzio MPC c/o Muttoni SA
Designer – Consorzio Ingegneri c/o Brenni engineering SA
Technology – BBRV wire
- 2** **Owner** – Swiss Federal Railway represented by AlpTransit San Gottardo SA
Main contractor – Consorzio MPC c/o Muttoni SA
Designer – Consorzio Ingegneri c/o Filipini & Partner SA
Technology – BBRV wire
- 3** **Owner** – Flughafen Zurich AG
Main contractors – Baltensperger AG, Schneider Stahlbau AG
Designer – STB Schnyder + Tobler
Technology – BBRV wire external
- 4** **Owner** – Eidgenössische Technische Hochschule Zurich (ETH)
Main contractor – Häring & Co. AG
Designer – ETH Zürich, Institut für Baustatik und Konstruktion (IBK)
Technology – BBR CONA unbonded

2 PT to avoid bearing displacement

For the neighboring 443m long railway bridge, the starting position was different. To take up the huge forces of a train braking on the bridge and to avoid displacement at the bearings, the requirements for the PT tendons were:

- tendon length – 5.5 to 12.2m
- tendon force – MBL between 1,990 and 5,270kN, two tendons per pier
- tendon type – must be exchangeable and electrically isolated

We proposed the use of external BBRV wire tendons improved with electrical insulation.

3 Deflection control for load transfer

Modifications to Zurich Airport's Terminal 2 required the creation of large new openings for placing escalators. The existing slabs were a composite construction of steel beams and concrete slabs. Six new steel beams up to 25m long had to be installed. Two external post-tensioning tendons – consisting of 52 x 7mm diameter prestressing steel wires – each with an MBL of 3,340kN, allowed deflection control during load transfer from the existing slab onto the new steel girders.

4 Wood strong enough for PT

In Switzerland, wood from deciduous trees is mostly burned, used for heating pellets or sold abroad. In the opinion of Professor Andrea Frangi from the Institute of Structural Engineering at the ETH in Zurich, this is very uneconomic. He believes it would be more sustainable, if the hardwood were first to be used for structural components, after that it could be processed into chipboard and finally it still could be burned in high temperature ovens to provide heating.

Together with his students, he searched for an optimized use for wood from deciduous trees, utilizing its good performance and the higher strength compared to pine. Finally, on the campus of the ETH Zurich, he constructed a four storey building – 'The House of Natural Resources' – which acts as pilot installation and office building at the same time. Over its lifetime, it will be monitored for forces, deformations, vibrations, temperature and humidity. The two wooden storeys of the house consist of a three dimensional frame structure on a column grid of 3 x 6.5m without any supporting walls. The laminated beams of each span are connected to the columns only by one monostrand post-tensioning tendon which has been pushed through the central cavity of the beams (4 x 0.6") – thus they are flexurally rigid. Special anchorages permit for regulation of the tendon force or the replacement of the load cell. A novelty is the composite slab of beech wood panels and concrete. The panels act as formwork as well as tension elements for the concrete. Machined recesses within the 40mm thick beech veneer panels take over the bond and shear forces.

The post-tensioning details for this project were:

- tendon type – unbonded PT tendons (greased, PE-coated monostrand)
- tendon length – 19.85m x 16 tendons
- stressing force – 700kN (MBL = 1,116kN).

UNIVERSITY RESEARCH EQUIPMENT, AUCKLAND & CANTERBURY, NEW ZEALAND

Testing facilities realized for two earthquake laboratories

SUPPORTING ENGINEERING EXCELLENCE



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With around 20,000 earthquakes recorded each year – most recently the devastating Christchurch quakes of 2010/11 – it is no wonder that New Zealand is often called the ‘Shaky Isles’. It is equally no wonder that the country’s universities have made a significant investment in research on the nature and effects of earthquakes, with the aim of ensuring that buildings can withstand the severest of quakes and, most importantly, protect the people within them.

The BBR Contech team has a decades-long connection with this work – educating undergraduates as guest lecturers on post-tensioning and concrete durability, supporting a wide range of seismic and other research projects – and, of course, providing an extensive range of services both to repair earthquake-damaged structures and to stop the damage happening in the first place. In 2015, these connections blended nicely into one, with two university-based projects that will enable students to test new theories in practical, hands-on ways.

1 Shaking things up in Auckland

In June 2015, the University of Auckland’s Centre for Earthquake Engineering Research called on BBR Contech to provide specialist grouting services for a ‘shake table’ in its new, fully enclosed test hall – part of the largest seismic testing facility in Australasia. The hall’s facilities are used for testing large-scale structural components and assemblies and to simulate earthquake forces, with technology enabling real-time views of the test results.

The shake table is an integral part of these experiments. Embedded in a pit and measuring about 3.6m x 2.4m, it comprises an 800mm-high concrete plinth with steel mounting points, to which is attached a large, 65mm-thick steel plate that can impose earthquake movements when loaded with a building structure.

BBR Contech’s role was to grout the steel plate in place using vibration resistant epoxy mortar. While this may sound straightforward, it actually required three phases over two days of intense concentration and incredible attention to detail to ensure that the plate was absolutely level, the grout was free of voids and the plate itself capable of ‘shaking’ to international research standards. The team had only one chance to get it right – and of course they succeeded, overcoming the dual challenges of a complex under-plate structure and the need to work quickly to place the 300 liters of grout within the working pot life and thus ensure an effective epoxy bond.

The team also supplied PT bars for another part of the test hall – a 13m wide x 3.7m-high strong wall and a 13m x 7.5m strong floor.



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Together, they enable students to assess the seismic capabilities of buildings up to three storeys high, with test assemblies connected to the wall and floor via fixings at 500mm centers.

Elsewhere at the University of Auckland, BBR Contech has continued to support a PhD student's research into the performance, design and use of FRP anchors to transfer forces from FRP strips into or through structural elements. The aim is to produce a robust design process for these anchors, so that efficient and strong FRP solutions can be developed for structures with complex geometries.

- 1 The shake table pit showing the concrete plinth and steel mounting points for the 65mm thick steel plate which will replicate earthquake movements.
- 2 The new fully-enclosed test hall takes shape at the University of Auckland's Centre for Earthquake Engineering Research.
- 3 Construction of the University of Canterbury's new structural earthquake laboratory is underway and due for completion in March 2016.
- 4 Facilities at Canterbury will include a 300m² strong floor and an 'L' shaped strong wall, both requiring post-tensioning.

TEAM & TECHNOLOGY

- 1 **Owner** – University of Auckland
Technology – Grouting, PT bar
BBR Network Member – BBR Contech (New Zealand)
- 2 **Owner** – University of Canterbury
Main contractor – Dominion Constructors
Project manager – The Project Office
Structural engineer – Aurecon
Technology – BBR VT CONA CMI internal, PT bar
BBR Network Member – BBR Contech (New Zealand)

2 More walls & floors further south

About 1,000km south of Auckland, the University of Canterbury is building a new, multi-million-dollar structural earthquake laboratory as part of its 'Canterbury Engineering the Future' program, which includes earthquake repairs, building extensions and new buildings for the College of Engineering. The new building will combine flexible learning spaces with room to test full-scale building systems under a variety of load conditions. Its facilities will include a 300m² strong floor and an L-shaped, 9.2m high, 1.6m thick strong wall with a

total length of 28m. The floor and wall will feature cast-in inserts at 400mm centers to allow test rigs to be attached. Working with main contractor Dominion Constructors, structural engineering firm Aurecon and project manager The Project Office, BBR Contech will supply, install, stress and grout 96 PT bars and 15 post-tensioning tendons in the wall and floor. It is an enormous investment – more than 3,600 cast inserts and coupler adaptors are needed for the inserts alone, while the total complement being imported for the job weighs about 80t! ●

PORT OF AUCKLAND, NEW ZEALAND

Repairs for busy maritime facilities

COASTAL COMMERCE – PROTECTING THE ASSETS





Way back in 1995, New Zealand's BBR Contech completed its first wharf repair project at the Port of Auckland. It must have gone well, because 20 years later the relationship is as strong as ever – and BBR Contech remains the repairer of choice for Ports of Auckland Ltd (POAL) and its main consultant Beca.

Established in the 1840s, the Port of Auckland is New Zealand's largest and busiest container and international trade port, connecting the country's importers and exporters with more than 160 ports in nearly 70 nations. It handles 37% of New Zealand's total seaport trade and 31% of its trade across all ports, including airports. It is also New Zealand's main port for cruise liners and vehicle imports. In the past 20 years, BBR Contech has been involved with repairs to six wharves associated with POAL operations – the Fergusson container terminal, the Bledisloe multi-purpose terminal – which includes a third container-ship berth – and the Captain Cook, Freyberg, Jellicoe and Queens Wharves, which handle everything from general – or breakbulk – cargo to steel, timber, vehicles and dry and liquid bulk products.

"The Port of Auckland operates 24-hours-a-day, seven-days-a-week, so it's vital that we keep it in good condition," says Pete Algie, Asset Manager for POAL, which manages the commercial freight and cruise ship harbor facilities.

"It's a constant process of monitoring, assessment, repair and remediation, especially given that many of the wharves are more than 50 years old. Time, tides and traffic have inevitable effects, and we need to manage the risks of damage and corrosion to the decks – and the beams and piles beneath." >

“It was a big project completed in a very constrained environment, but we managed to finish four weeks ahead of schedule.”



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Twenty years of service

Most of BBR Contech’s projects have involved conventional repair techniques, such as injecting epoxy resin to prevent the ingress of sea water to concrete deck slabs, and using hydro-demolition followed by applications of dry-spray guniting to exposed and damaged substructures. The latter approach has been particularly common, most notably in 2011 when BBR Contech repaired the 100-year-old Queens Wharf, the largest job of its type ever undertaken in New Zealand. “Queens Wharf was designated ‘party central’ for the 2011 Rugby World Cup,” says Mark Kurtovich, BBR Contech’s Development Manager. “Thousands of people were expected to gather there to watch the games and enjoy a wide range of concerts and other entertainment, so a number of stakeholders needed assurance that it was structurally safe and sound – at the time and into the future.

Unfortunately the substructure was badly in need of repair, so we were called in to fix it. That meant removing and reinstating more than 190m³ of concrete and replacing a significant amount of reinforcing bar – essentially replacing two-thirds of the wharf’s substructure. It was a big project completed in a very constrained environment, but we managed to finish four weeks ahead of schedule. With all the other projects going on at the same time, that went a long way to easing the pressure on both the wharf and the client.”

- 1 Aerial view of the busy Port of Auckland. Photograph courtesy of Ports of Auckland Ltd.
- 2 The BBR Contech team carrying out repairs to the sea wall between Jellicoe and Freyberg wharves.
- 3/4 Replacing reinforced concrete on Freyberg Wharf, named after the former Governor-General of New Zealand, was a challenging project.
- 5 Queens Wharf was ready for its role as ‘party central’ during the 2011 Rugby World Cup, thanks to completion of a massive structural repair program by BBR Contech.



“They also had to meet our rigorous health and safety standards and comply with our environmental management policy. It could have been a big headache, but somehow they made it easy.”

Peter Algie, Asset Manager, Ports of Auckland Ltd



Other POAL projects have included designing, installing and commissioning a cathodic protection system for the Fergusson container terminal in 2000, and repairing breastworks at Captain Cook Wharf in 2012. Then in 2014 another big project came along, this one involving five different wharves at the same time. It included:

- completing conventional concrete repairs to the Queens Wharf breastworks
- replacing a 15m² section of heavily reinforced concrete on the deck of Freyberg Wharf – a complex project given the large amount of steel involved and the challenges of working in a busy operational area
- undertaking substructure concrete repairs and installing Fabriform under Jellicoe Wharf and the Fergusson and Bledisloe container terminals. Originally developed by Construction Techniques in the 1960s, Fabriform is made by pumping highly fluid concrete mix into specially woven fabric ‘envelopes’, which are pre-positioned in areas vulnerable to erosion, such as seawalls.

“This was a particularly challenging project as it was based in some of the busiest parts of the port – and therefore a relatively dangerous workplace,” says Pete Algie.

“The BBR Contech guys had to contend with huge machines constantly on the move around the wharves, as well as the hazards of the marine environment when working on the substructures – not only the water and the tides, but also the tugs and other shipping vessels that constantly come and go.”

“They also had to meet our rigorous health and safety standards and comply with our environmental management policy. It could have been a big headache, but somehow they made it easy.”

Highly rated performers

Pete says this ability to deliver with minimal fuss is one of many qualities that have made BBR Contech a partner of choice for POAL and Beca. “They recognize that we work in a dynamic environment in which plans can change at short notice. They’re quick to adapt without complaint, they do a great job in keeping our wharves up to scratch and they leave the sites clean and tidy. Everyone at the port is very happy with BBR Contech – great work, great attitude.”

BBR Contech has more recently helped POAL with a diagnostic assessment of the port’s wharf condition. This will contribute to the company’s asset management strategy and its long-term repair and remediation strategy.

“We’re keen to look beyond conventional repair techniques – which may no longer meet our needs – to alternative approaches such as a greater use of cathodic protection systems,” says Pete. “BBR Contech’s practical experience will make a valuable contribution to our plans.” ●

TEAM & TECHNOLOGY

Owner – Ports of Auckland

Structural consultant – Beca

Technology – MRR range

BBR Network Member – BBR Contech (New Zealand)

HAMMERSMITH FLYOVER, WEST LONDON, ENGLAND

Bearing replacement for major arterial road flyover

UK'S LARGEST & MOST COMPLEX PROJECT

The Hammersmith flyover is an important four lane highway route linking the west with central London and is used by around 70,000 vehicles each day. When it opened in 1961, it was the first of its kind and featured the latest in construction engineering. Mark Bond from BBR Network Member Structural Systems UK tells how, over 50 years later, they have now contributed to its 21st century makeover with know-how and teamwork, resulting in the successful completion of one of the UK's largest and most technically complex strengthening projects.

- 1 Great precision and control was necessary to lower the new spherical bearings into the pits.
- 2 The Hammersmith flyover, an important route linking west and central London takes traffic over the Hammersmith gyratory system.
Photograph released into the Public Domain by Patche99z via Wikimedia Commons.

TEAM & TECHNOLOGY

Client – Transport for London (TfL)

Main contractor – Costain Limited

Lead designer – Ramboll Parsons
Brinckerhoff

Technology – MRR range

BBR Network Member – Structural
Systems (UK) Limited

We were appointed by main contractor Costain during the Early Contractor Involvement (ECI) phase in 2014, as part of their contract with Transport for London (TfL) to strengthen and repair the flyover. This involved designing a hydraulic jacking system that was capable of the lifting the flyover whilst also supporting the bridge under dynamic loading during the day when it was under live traffic conditions – a key strategy for the buildability of the scheme.

Specialist works undertaken

We undertook a huge volume of work for this project including:

- LVDT movement monitoring at 240 discreet locations, each capable of recording structural movements down to 0.1mm longitudinally, laterally and in rotation.
- Permanent pier strengthening to the piers made up of 48 high tensile bars and steel bracketry.
- Vertical box beam strengthening with 336 embedded and load tested bars.
- Temporary pier strengthening made up of 240 high tensile bars and individual, bespoke bearing plates.
- Pit wall strengthening consisting of 960 embedded, load tested and stressed high tensile bars.
- Installation and subsequent removal of 15 temporary bearings, each weighing 2,100kg.
- Removal of existing bearings and steelwork – some 6,000kg at each pier location.
- Installation of 34 permanent bearings, each weighing up to 2,400kg each.
- Design, installation and operation of 12 multipoint, synchronized jacking systems for the simultaneous control of the vertical and lateral movement of the structure. Each of the application jacks weighed 750kg and was capable of accommodating 16,000kN.
- 24 hour/7 day working and monitoring – and, yes, we even had a 'Merry Christmas' on site.





2

Changing the bearings

Changing the bearings was especially tricky, as they were situated within two meter deep pits which were only fractionally wider than the piers themselves. The replacements were spherical bearings which were considerably larger than the old roller bearings, making their handling and fitting a complex task in itself. From each pit, 6,000kg of existing bearings and stools were removed and replaced with 7,000kg of temporary works in the form of temporary bearings, jacks and plate to enable the bearing change. Then, 5,000kg of new bearings were installed and all the temporary works removed.

Jacking system

Using our specialist experience, we worked collaboratively with the project team to develop bespoke jacking and monitoring systems to minimize risks. The system allowed the flyover to be supported by hydraulic jacks on up to five piers at any one time, allowing bearing replacement to be performed simultaneously – whilst achieving a precise tolerance by accurate monitoring of load/levels – across pier groups. This feat of hydraulic engineering not only enabled the flyover to remain open during the day, but also ensured maximum efficiency during bearing replacement work. The SSL UK mobile jacking control unit was custom-built to connect into our bridge monitoring and hydraulic jack system.

Engineering skills to appreciate included installing up to 2,400kg bearings to a 0.1mm accuracy in all planes and in relation to the adjacent bearing, all surveyed and installed within the two meter deep pit under the bridge. Site congestion was high as the continuously re-orientated bridge was supported by primary hydraulic jacks while being monitored by sensors to ascertain the exact position of the piers and abutments.

Project delivery

The Health and Safety Plans for the lifting and jacking operations were carefully coordinated and closely supervised which resulted in no loss-of-time incidents. We improved project delivery by reducing the full bearing replacement process for one pier from 43 working days for the first pier, down to just 21 days for the last, from first lift to final de-jacking onto permanent bearings. Even when the complete program sequence was changed by designers mid-way through the works due to unforeseen bridge conditions, together, we were able mitigate the delay. The team achieved every one of the client's milestone dates throughout the project – and achieved practical completion a month ahead of program. We now look forward to taking our creativity in designing and delivering a workable solution to these complex engineering requirements, along with our trusted management techniques, forward to our next challenge. ●

“Structural Systems’ approach to engagement and collaboration was exemplary and they were a pleasure to work with from the early stages of developing and agreeing the conceptual arrangements for jacking through to the detailed implementation. The challenges that we collectively faced were significant and Structural Systems were proactive and positive throughout the process leading to delivery of a successful solution and in working to the extremely high levels of precision required, all within an extremely demanding programme.”

Matthew Collings, Project Director,
Ramboll Parsons Brinckerhoff, Lead Designer

“The challenge for the project team was to carry out the works to strengthen and refurbish the flyover with minimal effect on the flow of traffic. This could not have been achieved without the support and co-operation throughout the supply chain, of which Structural Systems Ltd (SSL) played a significant part. SSL devised a methodology so that any works to replace the bearings, that had an effect on traffic, were carried out during night-time possessions of the flyover between 22:30-05:00hrs, which was implemented without any over-runs into the morning peak. They also constantly improved their methodology to reduce the number of night-time possessions required. This was all carried out against a main programme which was changing due to the realization of unforeseen risks, to which SSL worked proactively with the project team to the mitigate delays. Overall SSL have been a critical part of the delivery of a successful project.”

Graham Carter, Transport for London

“SSL were asked to deliver a technically complex sequence of pier strengthening, jacking and bearing replacement, safely without disrupting peak time traffic flows and all to an accuracy of 0.1mm, which is exactly what they did without issue or incident.”

Andy Bannister, Project Manager, Costain

MIDTOWN & ROYAL DOMAIN APARTMENTS, MELBOURNE, AUSTRALIA

Façade remediation projects

TAKING THE LEAD IN FAÇADE REMEDIATION

A major project at one of the busiest intersections in Melbourne has recently been finished, reports Andrew Bray of Australian BBR Network Member SRG. The project involved completing remedial works to the Midtown façade, situated on the corner of Bourke and Swanson Streets in the middle of the city's thriving CBD, for client ISPT.

ISPT is one of Australia's largest unlisted property fund managers with over A\$11 billion of funds under management through investments in office, retail, industrial and residential properties. They own high quality property and create office and retail spaces that meet the changing needs of their tenants. Our project was for remediation work to the seven storey main tower and adjoining two storey building and involved concrete and render repairs, brickwork repairs, glass window replacement and repairs and coating works, as well as a major roof upgrade to the two storey building. The works were deemed necessary after independent engineering inspections indicated full façade remediation was required to fix spalled concrete and detached render.

Remediation projects are always very intricate and detailed and Midtown was no different. SRG is skilled at managing projects of this nature – one of the reasons why it was a success.

1 Stakeholder satisfaction

The building was fully tenanted at the time, with a number of high profile businesses – such as banks and telecommunications companies – continuing to trade as work was carried out. With many high profile stakeholders, client liaison was crucial in order for the works to run to program, whilst maintaining unencumbered access to shop fronts and commercial properties so that they could continue with their daily business. With little road access, coverway gantries were erected over Little Bourke Street and along the front façades of Bourke and Swanston Street. Mixed use access including swing stage scaffolds, booms, scissors, rope access and mobile scaffolds were incorporated into the works to enable all traffic – road and pedestrian – to continue to use the building as normal, whilst maintaining visibility to the site to ensure that third parties were not deterred from entering businesses and the arcade area of the building.

The major challenge for the project was co-ordination with, and communication to, the many stakeholders involved in the project, which also required a myriad of planning permits – and compliance with noise restriction regulations. It is significant that SRG coordinated material delivery and scaffolding to the

center of Melbourne – most of these activities were completed during the night or outside of normal working hours, with liaison required between the City of Melbourne, Yarra Trams and all essential services including the police and fire brigade. Thanks to the strong relationships we had developed with the numerous stakeholders who had an interest in the project – including the client ISPT and Melbourne City Council, constraints were overcome through intense logistics planning and weekly meetings between all parties involved in the project.

Cohesive project team

The cohesive nature of the project team ensured that all matters were discussed transparently with a key focus on ensuring that unencumbered access for the works to continue were met, whilst abiding by the City of Melbourne requirements and requests for all tenancies to remain operational. In most cases, months of planning were necessary given that another major construction site was also underway nearby, which meant that traffic management was required for necessary crane lifts so neither project was delayed. This clearly demonstrates our ability to take a leadership role and the transparent, high-integrity approach we take to all our projects.



1



2



3

Excellence Award

The project was completed ahead of schedule, to budget and to the high standards clients have come to expect from SRG. In recognition of the complexity of the work, we were also awarded the Australasian Concrete Repair Association (ACRA) Award for Excellence for 'Building and Remediation over A\$2M' for the Midtown Façade Project.

As a result of the works carried out at Midtown, its façade now adds quality to the appearance of one of the busiest mall precincts of the city. It was a remarkable project, undertaken with our usual great attention to detail.

2 Royal Domain Apartments

Aaron Callegari of SRG's Services Division reports that the team has completed remedial works at the Royal Domain Apartments on St Kilda Road, also in Melbourne.

The façade includes many decorative architectural mouldings made of polystyrene which had become detached from the main concrete structure. These elements are being reattached using stainless steel pins, as well as a comprehensive patching and coating system to revitalize the iconic building's façade.

Initially the client wanted to split the contract into two separate stages to minimize the impact on residents, however, once SRG commenced works on site, the feedback from tenants who were encouraged by the building's facelift and the quality of workmanship being performed, meant that phase two of the works was brought forward. In addition to the positive comments received from the client and major stakeholders, the main material supplier for the project has also praised the outstanding quality and workmanship of our remedial technicians. Congratulations to everyone who has been involved in this project – living up to our value of excellence. ●

- 1 Work underway on the Midtown façade at one of Melbourne's busiest intersections.
- 2 Close-up view of the SRG team at work on remediation of the Midtown façade.
- 3 Work is almost completed on the facelift at the Royal Domain Apartments.

TEAM & TECHNOLOGY

- 1 **Client** – ISPT
Technology – MRR range
BBR Network Member – SRG Limited (Australia)
- 2 **Client** – Royal Domain Plaza Owners Corporation
Technology – MRR range
BBR Network Member – SRG Limited (Australia)

BARWON RIVER BRIDGE, WINCHELSEA, VICTORIA, AUSTRALIA

Strengthening infrastructure with carbon fiber technology

NEW STRENGTH FOR BRIDGE

As part of major improvements to the Princes Highway, Andrew Bray from Australian BBR Network Member SRG, reports that his company has strengthened a bridge over the Barwon River in Winchelsea, Victoria with carbon fiber.

When a wooden bridge was constructed over the picturesque Barwon River in the mid 1800s, the town of Winchelsea was created – and a new gateway to the western districts of Victoria was established. Floods swept away the first Barwon Bridge in 1849 and a new bluestone bridge was opened in 1867. During the next century, a second bridge was constructed adjacent to the bluestone bridge. It is this bridge that we have been working on.

Project outline

Strengthening works commenced in January last year, following the installation of a fixed scaffold access system set up beneath the 61m long bridge to span over the Barwon River.

SRG was responsible for the provision of access, supply and installation of carbon fiber strengthening and various associated works, including concrete repair to deteriorated sections of the bridge.

In total over 3km of carbon fiber laminate was required to strengthen the three spans of the bridge.

Construction challenges

Challenges of the project included close monitoring of environmental conditions to ensure the carbon fiber adhesive achieved a suitable bond strength and some design modifications required at the bridge piers.

All works were completed ahead of program and to the satisfaction of the client, VicRoads, and the head contractor, Cut and Fill. This is a testament to the great work carried out by our crew.

In addition to the vast experience that SRG has acquired in applying FRP – both fabric and plate – to a host of different structures, our 'in-house' design capability is available to support the requirements engineers and owners alike. ●



2

What is carbon fiber?

Carbon fiber is an extremely strong and lightweight material consisting of crystalline filaments of carbon and is used as a strengthening material.

How does carbon fiber strengthening work?

Carbon fiber strengthening involves the external application of carbon fiber materials to concrete in order to increase the flexural, shear, axial or seismic resistance of a structure. There are other materials with similar properties to carbon fiber, including Kevlar or aramid which can also be used to strengthen structures. These materials are typically referred to as fiber reinforced polymers (FRP) and are available as either a fabric wrap or as stiff laminate plates. They are generally applied using a high strength epoxy resin to bond the material to the structure in accordance with an engineering design.



1

- 1 Strengthening work was carried out from a fixed scaffold access system set up beneath the 61m long river bridge.
- 2 Over 3km of carbon fiber laminate was installed to strengthen three spans of the bridge.

TEAM & TECHNOLOGY

Client – VicRoads
Main contractor – Cut and Fill
Technology – MRR range
BBR Network Member – SRG Limited (Australia)



TECHNOLOGY

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-

BBR VT CONA CMI ELECTRICALLY ISOLATED TENDON

Most advanced multi-strand post-tensioning system

HIGHEST POSSIBLE CORROSION PROTECTION

The European assessed BBR VT CONA CMI Electrically Isolated Tendon (EIT) is the most advanced multi-strand post-tensioning system with the highest possible level of corrosion protection – PL3 – as specified in the latest *fib* recommendations. Dr. Behzad Manshadi, BBR VT International's Head of Research & Development outlines the features and benefits of the system.





1

The ultimate PT system

Quality control, durability and long-term monitoring of PT tendons are required. Combined with a simple and non-destructive method of measuring the impedance of the tendons makes this the ultimate post-tensioning system for achieving the highest level of protection – PL3.

The CONA CMI EIT is a multi-strand post-tensioning system for internally bonded applications and provides excellent performance including situations where enhanced safety, corrosion protection, quality control, durability and long-term monitoring of post-tensioning tendons are required.

Standard sizes

The standard tendon sizes range from O2 to 31 seven-wire prestressing strands. Both 15.3mm strands with a cross sectional area of 140mm² and 15.7mm strands with a cross-sectional area of 150mm² are possible, whereas the maximum characteristic tensile strength for both strands is 1,860MPa.

Operation & advantages

The CONA CMI EIT is the most compact and light-weight system available on the market. The tendon force is transferred to the concrete using an advanced and proprietary three-plane load transfer element, allowing for very small center spacing and edge distances at the anchorage. Furthermore, the full post-tensioning load can be applied at very low concrete strength $f_{cm,0}=19/23\text{MPa}$.

Anchorage configuration

The main components in the anchor zone of the CONA CMI EIT system are the protection cap, wedges, anchor head, isolation ring, load transfer element (bearing trumplate) and trumpet. In the anchorage zone, the BBR VT Plastic Duct is connected to the trumpet and the strand bundle is spread out towards the anchor head, where each strand is individually locked with a CONA CMX wedge. Lastly, the protection cap with the help of the isolation ring encapsulates the whole anchor head and wedges. CONA CMI EIT tendons can also be coupled with the Type H fixed coupler.

Thick corrugated BBR VT Plastic Ducts eliminate the ingress of water and chlorides and anchor head encapsulation prevents stray currents from causing electro-chemical corrosion of the prestressing steel. This – combined with a simple and continuous method of measuring the impedance of the tendons – makes CONA CMI EIT the ultimate post-tensioning system for achieving the highest level of protection with an early detection warning system.

But there's even more – the system has been successfully tested in accordance with procedures specified by the latest *fib* recommendation (Bulletin 75) and, thus, the BBR VT CONA CMI EIT range has been approved for the optional use category 'electrically isolated tendon' in accordance with EAD 160004-00-301 – which supersedes ETAG 013 – and in accordance with the Swiss guideline '*Leitfaden für die technische Zulassung von Spannsystemen in der Schweiz*'. ●

Key features

- High electrical resistance minimizing risk of stray currents causing electro-chemical corrosion of steel
- Thick corrugated BBR VT Plastic Ducts prevent water and chloride ingress
- Highest possible protection level (PL3) according to *fib* recommendation to enhance safety and provide superior long term durability
- Continuous monitoring of electrical impedance resulting in early detection warning system
- Standard tendon sizes from O2 to 31 strands. Larger sizes upon request
- Optimized for 15.7mm diameter, 1,860MPa strand
- Most compact & light-weight system available utilizing an advanced proprietary load transfer element for very small center spacing & edge distances at anchorages
- Application of full post-tensioning force at very low concrete strengths
- Fixed couplers for joining tendons
- BBR VT Plastic Ducts filled with high performance BBR grout
- European Technical Assessment and CE marking

1 The BBR VT CONA CMI Electrically Isolated Tendon (EIT) is the most advanced multi-strand post-tensioning system for eliminating the ingress of chlorides and preventing stray currents from causing electro-chemical corrosion of the steel.

BBR VT CONA CMI ELECTRICALLY ISOLATED TENDON

Testing of anchorage-duct assembly & BBR VT Plastic Duct system

PUTTING TECHNOLOGY TO THE TEST

BBR VT International has a long track record and commitment to testing of its new technology and techniques before making them available for use worldwide. The BBR HQ R&D team now share some aspects of their testing procedures for BBR VT CONA CMI Electrically Isolated Tendons (EIT).



1

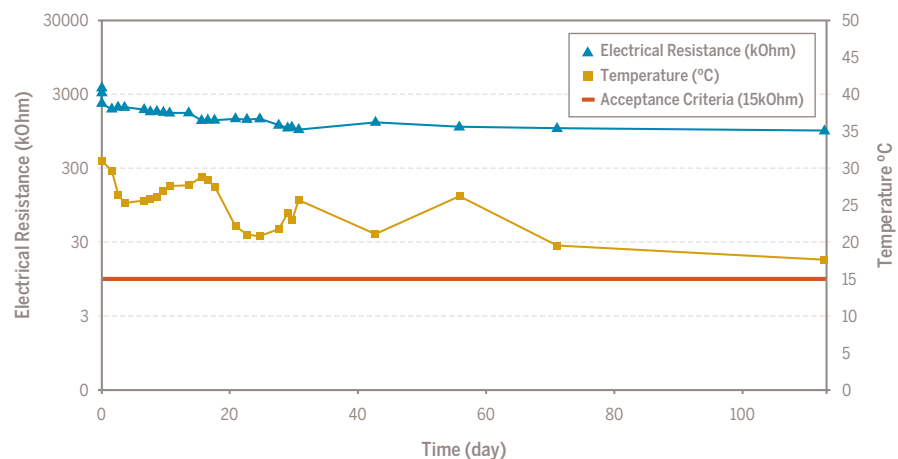
EIT performance of BBR VT CONA CMI anchorage-duct assembly

This test was carried on the anchorage-duct assembly, again in accordance with “fib Bulletin 75: Polymer-duct systems for internal bonded post-tensioning”. A BBR VT CONA CMI anchorage – consisting of 12 strands of 15.7mm diameter each, ring wedges, bearing trumplate, steel ring, anchor head, trumpet and plastic protection cap – was assembled and connected to a specimen of ID 75 BBR VT Plastic Duct using a BBR VT round duct slip-on coupler. The connection was sealed using a heat-shrinkable sleeve.

The test specimen was immersed vertically, for almost four months, inside a container filled with saturated Ca(OH)₂ (calcium hydroxide) solution. During this time, the electrical resistance was measured using an LCR meter between the bar connected to the bearing trumplate and the electrical wire connected to the anchor head and protruding from the protection cap. The level of electrolyte and quantity of Ca(OH)₂ were continuously monitored by pH indicator paper and found to be between 12-13. The temperature of the testing room was also measured by thermometer and recorded, together with each electrical resistance measurement.

Electrical resistance, together with the temperature behavior of the testing specimen, were measured and recorded over a period of 112 days. The test procedure fully meets the intent of the test specification and the measured electrical resistance considerably exceeded the specified minimum value of 15kOhm during the entire duration of the test. Thus, the BBR VT CONA CMI EIT complies with the requirement given by EAD 160004-00-301 – which will replace ETAG 013 – and in accordance with the Swiss guideline “Leitfaden für die technische Zulassung von Spannsystemen in der Schweiz”.

- 1 These two images show how a fully assembled specimen BBR VT CONA CMI anchorage was immersed for almost four months in a container filled with saturated Ca(OH)₂ solution and electrical resistance was measured, along with temperature.
- 2 This graph shows that measured electrical resistance, over a period of 112 days, of the BBR VT CONA CMI EIT specimen considerably exceeded the specified minimum value of 15kOhm.
- 3 One meter specimens of three configurations of all sizes of BBR VT Plastic Duct were immersed in water for more than 24 hours and the measured electrical resistance of all permutations of the duct system exceeded the specified minimum value of 2,000kOhm.



2



3

EIT performance of BBR VT Plastic Duct system

The test was carried out on BBR VT plastic duct in accordance with *fib* Bulletin 75. In order to confirm the electrical resistance properties of the duct system intended for use with EIT tendons meeting the PL3 criteria, three duct configurations were tested – the duct alone, duct with connector and duct with connector and vents. One test per size was performed on all duct sizes and each configuration mentioned above.

A one meter specimen was prepared in each case and the ducts with connectors were sealed using heat-shrinkable sleeves. A steel rod was concentrically installed into the test specimens and the duct specimens were filled with tap water and thereafter both ends of the specimen ducts were sealed.

The electrical resistance was measured while the test specimens were immersed horizontally for more than 24 hours in a water tank with their ends sealed against the walls of basins inserted into the tank. To achieve this, an LCR meter was used to record resistance between the bar which was in contact with water inside the duct, and the basin that was connected to the water tank.

The measurements of electrical resistance for all permutations of the duct system specimens exceeded the specified minimum value of 2,000kOhm. ●

TECHNICAL UPDATE

BBR E-Trace

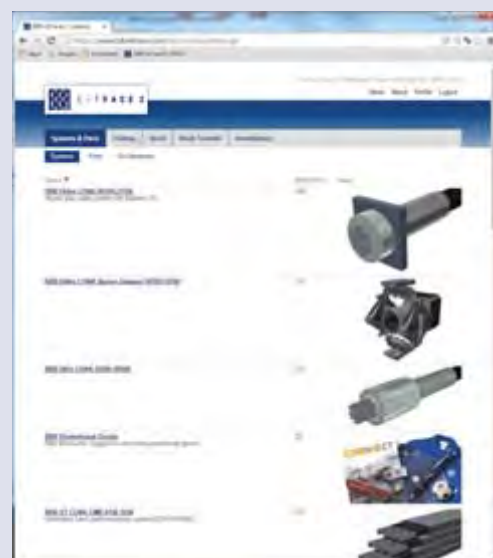
UP-TO-DATE TRADING & QA PLATFORM

The BBR Network's internet-based trading and quality assurance platform has been updated and enhanced. BBR VT International's Product & Quality Manager, Christian Roost, talks us through the strategy and changes.

BBR E-Trace – our in-house developed internet-based software – links all members of the Global BBR Network including BBR PT Specialists, BBR Component Manufacturers (CMs) and ETA Holder, BBR VT International. This comprehensive e-commerce platform leads users through the quality process, ensuring that each step through the production and supply chain is properly documented and recorded. The platform facilitates the everyday work of all BBR Network Members and also supports effective supply chain management. Essentially, the BBR E-Trace platform allows us to achieve 100% traceability of every single BBR component, as well as an optimal full Factory Production Control, both essential to ensure and maintain the CE marking in BBR systems. After more than five years since the launch of BBR E-Trace, it was time to update the system and add some new features. First of all, we have changed the design and the navigation to be more

comfortable to operate. Then our programmers invested more than 500 working hours in reprogramming the system to the newest code standards and yet more programming hours to make new features and tools. The purpose of the new code was to create a faster and yet robust platform which can be easily extended for future BBR systems and applications. New features, such as the kit generator, are already established and have been used many times, providing a superlative increase of productivity in terms of sourcing to the BBR Network.

The updated BBR E-Trace has been online now for six months and feedback has been very positive. We are continuously working on this trading system to ensure that the platform remains up-to-date. The team here is looking forward to developing still further new tools and features to make BBR E-Trace even more useful for our customers and component manufacturers. ●



TECHNICAL UPDATE

New approvals, extensions & renewals

TRIO OF NEW TECHNICAL ASSESSMENTS

Over recent months, three new assessments have been secured for technologies within the BBR VT CONA CMX range. European Technical Assessment for the CONA CMO system has been secured, along with new assessments for the CONA CMB and CONA CMI systems.



BBR VT CONA CMO – onion

The European Technical Assessment, ETA-15/0808, of the new BBR VT CONA CMO anchorage has been issued. The key features and benefits of this new multi-strand post-tensioning system are:

- For internally bonded post-tensioned applications particularly in very thin concrete cross-section such as slabs
- Economical solution for fixed-end anchorages compatible with BBR VT CONA CMF, CONA CMI SP and BT systems
- Standard tendon sizes from 2 to 6 seven-wire prestressing strands
- Optimized for 12.9mm & 15.7mm diameter, 1,860MPa strands
- Full stressing at very low concrete strength ($f_{cm,0}=21/26\text{MPa}$)
- No anti-bursting or splitting reinforcement required
- Equipped with an innovative clip-lock design of the bulb-strand spacer, increasing productivity during anchorage installation
- Very small center spacing and edge distances at anchorages
- Compatible with corrugated flat or round tendon duct utilizing either galvanized steel or plastic material.

- 1 The new BBR VT CONA CMO Onion multi-strand anchorage, with a flat array of onion-bulb strand ends, is designed for internally post-tensioned applications – particularly suited to use in very thin concrete cross-sections, such as slabs.
- 2 The features of the BBR VT CONA CMB Band system make it ideal for use in the prestressing of wind towers and also the strengthening of bridges and tanks.
- 3 As well as for silos, nuclear power plants, stadiums and a wide range of other special applications, the BBR VT CONA CMI internal system, with its superior cryogenic performance, is perfect for LNG/LPG tank applications.



2



3

BBR VT CONA CMB – band

The BBR VT CONA CMB Band European Technical Assessment ETA-10/0065 has been issued. The new assessment is based on the previous CONA CMB European Technical Approval and has the following key features:

- For external unbonded post-tensioned applications
- Standard tendon sizes from 1 to 16 seven-wire prestressing strands
- Optimized for 140mm² & 150mm², 1,860MPa strands as well as for 165mm², 1,820MPa compact strands
- Consists of bands with 1, 2, or 4 prestressing strands
- Offering a high level of corrosion protection, it is widely used for the prestressing of wind towers, strengthening of bridges and tanks
- Steel prestressing strands are factory provided with a corrosion protective material and an extruded double or single HDPE protective sheathing
- Tendons with single sheathing and tendons with double sheathing are each in two configurations:
 - individual strands connected with webs (monolithic configuration)
 - individual monostrands without interconnections
- Full stressing at concrete strength ($f_{cm,0}=29/35\text{MPa}$).

BBR VT CONA CMI – internal

The European Technical Assessment ETA-06/0147 has been issued for BBR VT CONA CMI, the most up-to-date and advanced multi-strand post-tensioning technology. Compared to the previous CONA CMI European Technical Approval, this assessment incorporates the following new key features:

- Extending the optional uses of the system:
 - Tendon for cryogenic applications
 - Encapsulated tendon
 - Electrically isolated tendon (see pages 80 & 81)
- Introduction of new BBR system grouting accessories:
 - Grouting & protection caps
 - Accessories for inlets and outlets
- New 2-segment CONA CMX O6 wedge Type Z – this wedge can be used on the full CONA CMX range of post-tensioning systems and is particularly useful in geotechnical applications where soil and mud may clog the wedge teeth of conventional 3-piece wedges (Type H and Type F) from properly gripping the strand. ●

A complete series of the latest approvals – along with CAD drawings and technical brochures – is available for download from our website – www.bbrnetwork.com/downloads/approvals.html



TECHNIQUES

Enabling monitoring of PT tendons with BBR VT CONA CMI EIT

QUALITY WITH CONTROL



1

BBR HQ and BBR Network Member Stahlton AG have been working closely together to extend the BBR VT CONA CMI system to EIT standards which will allow customers to benefit from additional features, such as monitoring of the post-tensioning installation. Jürg Däniker of Swiss BBR Network Member, Stahlton AG, presents some background information and a pictorial overview of key stages in the installation of the CONA CMI EIT system.

If it can be verified that post-tensioning tendons are encapsulated and completely watertight, it is safe to assume that no corrosion will occur on the steel strands, anchor heads and wedges. Taking this a stage further, if it is possible to monitor this at any point during the lifecycle of the tendons, meaningful predications can be made about the health of the post-tensioning. Furthermore, reliable electrical isolation will protect the steel post-tensioning strands from any damage caused by sparking of any stray current passing through the tendon. The risk of stray currents arises mainly when the post-tensioned structure is located near to railway tracks and especially around installations using direct current (DC), such as rail or tramways.

Collaborative development based on experience

To extend the BBR VT CONA CMI system to meet the EIT standard, BBR VT International has been working closely together with Swiss BBR Network Member Stahlton AG because of their long track record of working with electrically isolated tendons – using both the BBRV wire and CONA strand systems.

The first bridge executed with EIT tendons by Stahlton was back in 1996. Since then, it has become common in Switzerland to construct railway and highway bridges, as well as other important structures which are subject to aggressive environmental influences like de-icing salt or stray current, using electrically isolated tendons. Or sometimes the EIT approach is chosen just so the option of monitoring the system is

available. In Switzerland, the EIT standard is not only applied to post-tensioning systems, but also to permanent soil or rock anchors.

Responsibilities, purpose & planning

To fulfil the high requirements for EIT tendons, it is essential that the responsibilities of all companies involved – owner, consulting engineer, supervisors, contractors and PT specialist – are clearly understood and outlined. From the outset, the purpose that the EIT tendons are to serve – protection against stray current, performance monitoring or fatigue – should be specified by the client, as this will dictate the EIT system specification. Where there are no national acceptance criteria and tolerable rate of failures available, then the system must be specified according to the aim of the EIT tendons – and the project – prior to execution. Complete wiring installation diagrams – including the earthing concept and location of the measuring control box or boxes – should be completed at project design stage. All project team members will need to understand the interfaces between the EIT system and their own work elements. It is also important that a thorough risk assessment and management process be agreed by all parties, as effectiveness of an otherwise high quality EIT installation by a PT specialist may be affected by the work of others on the project.

The improved protection level offered by the BBR VT CONA CMI EIT post-tensioning system is an important milestone on the road to achieving more durable and maintainable structures.

1 Pictured here working with the site team, Jürg Däniker (top) believes that the improved protection level offered by the BBR VT CMI EIT post-tensioning system is an important milestone on the road to achieving more durable and maintainable structures.

STEP-BY-STEP GUIDE



1

1 BBR VT Plastic Duct is cut to length, then vents at high and low points are built in and sealed to the duct using a heat shrinkable sleeve.



2

2 Once the ducting and bearing trumplates have been positioned and sealed with heat shrinkable sleeves, the steel strands are pushed through the duct in the normal way.



3

3 The anchor head, wedges and wedge retaining plate can now be installed and the electrical measuring cable, in this case a 25mm² cross-section wire for measuring stray current, can be fixed to the anchor head.



4

4 A plastic protection cap is placed over the anchor head to seal it off. Various strengthened positions in the cap allow for holes to be drilled for mounting the grouting port and cable gland to suit the local situation. For this particular construction project, the standard grout connection has been closed and sealed with silicone and a yellow cap, as space limitations meant that the grout pipe could not be placed from behind. Thus, a new hole was drilled in the side of the cap which is not visible in the picture.



5

5 Wiring of the tendons to the measuring box. The location of the measuring box, along with the earthing concept and overall wiring scheme must be planned well in advance.



6

6 The connection of the wiring to the measuring box is the final stage in installing the BBR VT CONA CMI Electrically Isolated Tendon system. Shown here is a measuring box for four tendons, plus an earth cable. ●

INSIGHT

Construction technology to promote sustainability

MAKING GREENER FOOTPRINTS

With the benefit of increased knowledge about the way in which we live and our environment, it has been clear for some years now that taking a sustainable approach is important to our own health and well-being – and that of our planet. Dr. Behzad Manshadi, BBR VT International's Head of Research & Development reviews how key developments in the field of construction technology have – and continue – to reduce the environmental impact of the industry's activities.



1

Back in 1987, the United National General Assembly Report of the World Commission on Environment and Development, entitled *Our Common Future*, defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” Sustainability has been described as at the point where economic, social and environmental priorities converge and this applies equally to the construction sector. For our industry, these priorities can be defined as:

- **Economic** – whole life approach, maintenance & decommissioning and user disruption
- **Social** – neighbors, users and construction workers
- **Environmental** – minimizing impact, CO₂ (entire lifetime), reusability and recyclability

The use of post-tensioned concrete offers advantages when measured against all of these criteria. Post-tensioning – originally developed in the 1940s in response to materials shortages – was the first key construction technology development on the road to greater sustainability.

Sustainable post-tensioning

Considerations for the creation of a sustainable post-tensioned structure must include both the short and long-term impacts of the structure. Durability of construction

is a crucial factor in lowering the structure's long-term environmental impact.

Optimum corrosion protection of post-tensioning tendons – to prevent ingress of water and thus chloride induced corrosion for high-strength steels – has been a critical factor in the long-term performance of post-tensioned concrete structures.

Meanwhile, practically no non-destructive techniques are available for monitoring and inspection of these tendons.

In the last two decades, the BBR Network – and indeed the whole industry – has adopted a multi-layer approach to corrosion protection for new post-tensioning tendons to achieve the required serviceability, safety and durability.

Evolution of electrically isolated tendons

At the beginning of the 1990s, a new generation of thick-walled corrugated polymer ducts for bonded internal tendons was developed and gradually introduced onto the market. The main purposes of these ducts was generally to improve the performance of the enclosed tendons – and last on the list of their possibilities was to make electrical monitoring of the tendons feasible.

In 2000, based on industry applications and actual knowledge, “*fib Bulletin 7: Corrugated plastic ducts for internal bonded post-tensioning*” was issued as a non-enforceable guideline for corrugated plastic ducts.

1 Sustainability has been described as at the point where economic, social and environmental priorities converge and this applies equally to the construction sector.

2 Following the *fib* recommendation, several bridges and viaducts for new high-speed railway lines have been designed and constructed with simply supported spans realized with partial or total pre-casting of the decks.

3 The electrically isolated anchorages permit easy monitoring and inspection of the tendons simply by measuring the electrical impedance between the high-strength steel inside the ducts and the normal external reinforcement.



2



3

The first so-called Electrically Isolated Tendons (EIT) were developed in Switzerland in the mid-1990s when the post-tensioning industry, Swiss Federal Road Authorities, Swiss Federal Railways and research institutions jointly worked on the system components, their design, inspection and associated monitoring techniques. The EIT technology used a tight polymer duct to encapsulate the high-strength steels and reduce fretting fatigue, grouting that creates a protective alkaline environment for the strands and an isolation element to electrically isolate the anchor head and wedges from the ground and the rest of the structure.

The electrically isolated anchorages permit monitoring and inspection of the tendons by measuring the electrical impedance between the strands and the external normal reinforcement. Monitoring over time allows the identification of the penetration of water – containing chloride – at defects in the ducts and coupling joints. Thus, for the first time, a simple and cost-effective early warning system was available to provide alerts as to whether maintenance of post-tensioning tendons was required.

Swiss guidelines made global

Based on substantial experiences of using tendons with thick-walled corrugated ducts with or without electrical isolation, a first guideline “*Massnahmen zur Gewährleistung der Dauerhaftigkeit von Spanngliedern in Kunstbauten*” was published jointly by the Swiss Federal Railways (SBB) and the Swiss Federal Roads Authority (ASTRA) in 2001.

This guideline recommended a multi-layer protection approach as design strategy and three categories for post-tensioning tendons in terms of corrosion protection were proposed:

- Category (a) tendons – in traditional corrugated steel duct.
- Category (b) tendons – specifies use of corrugated polymer ducts for enhanced protection.
- Category (c) tendons – must be electrically isolated.

The guideline gave indications for the choice of the tendon category, measuring instructions, limits of the electrical resistance and orientation for the interpretation of results.

The guideline became the basis for publishing the “*fib Bulletin 33: Durability of post-tensioning tendons*” introducing worldwide three protection levels (PL). Electrically isolated tendons fulfill the requirements of the highest protection level PL3 according to this *fib* Bulletin.

Present position

In the last 20 years, an increasing number of bridges, flyovers and viaducts have been constructed – mainly in Switzerland – with electrically isolated tendons according to Protection Level 3 (PL3). Similar systems following the *fib* recommendation have recently been applied in Italy for the design and construction of several bridges and viaducts for new high-speed railway lines on simply supported spans realized with partial or total pre-casting of the decks. The most recent development in

standardizing the direction of EIT technology has been the new *fib* recommendation “*fib Bulletin 75: Polymer-duct systems for internal bonded post-tensioning*” which was published in 2014. Compared to *fib* Bulletin 7 issued in 2000, this adds extensive information about material components, fabrication processes, on-site installation, as well as testing and approval for the duct systems. In particular, Chapter 7 and Annex B provide testing details that can be considered as a solid basis for European (EAD 160004-00-301) and Swiss guidelines for standard evaluation of encapsulating and EIT performance of the duct system and anchorage duct assembly.

Electrically isolated tendons are now a proven system with which to enhance the durability of structures with post-tensioning tendons and thus a definite trend towards large worldwide usage of these tendons in a sustainable construction manner is anticipated.

The main factors influencing the success of electrically isolated tendons are high quality material and components, along with a detailed design focused on the critical aspects, proper testing, the personnel skills and experience in execution and the respect of well-established construction procedures. BBR HQ provides the highest quality construction technology and is committed to both testing and training, while the BBR Network is qualified to advise at the earliest stages of a project and provide professional installation of all BBR technology, including BBR VT CONA CMI Electrically Isolated Tendons. ●

THINKING ALOUD

David MacGeorge, Managing Director of SRG Limited – the BBR Network Member for Australia, Hong Kong and the Middle East – explores how harnessing a changing environment leads to business strength



OWNING A CHANGING ENVIRONMENT

We often operate under challenging conditions, tight deadlines and in complex situations. Owning these changing environments and having the courage to harness challenges is key to defining what a business stands for. Given the innovative history and track record of BBR, this is something that fellow BBR Network Members will understand and endorse completely.


Against this backdrop, our Prime Minister has put innovation at the top of his agenda and has recently released a policy that focuses on start ups, research institutes and the wider economy. Innovation has a place at the business table no matter the size of your organization – and is vital to success in times of turbulent market conditions. In the past year, we have embarked on a journey to reshape our business and enable it to compete successfully in these challenging construction and resource market conditions. We took what some might regard as a bold approach and completely rebranded our business. In doing this, we sent a clear message to our investors, market, business partners and indeed our own staff. Our rebranding has been about moving away from siloed business units – knowing that we needed to harness the power of the group as a whole. Uniting the company has allowed us to leverage our combined expertise, skills and technical excellence and has carved out niche offerings and services that allow us to continue to succeed and prosper. One way in which we have leveraged our talent is through the formation of a dedicated team, who create products that solve technical challenges in the industries

we work in. They are able to combine specialist areas of engineering, outside of the standard field of structural engineering, to design solutions that ensure simplicity and affordability. In fact, we have just patented our first new product and it is now being distributed around the world. Tackling problems that others won't has allowed us to grow a business stream and means we're known in the industry as innovative problem solvers. Having the courage to act when problems are brought to us continues to deliver dividends for our business and customers. In addition, we have built a strong alliance of partners, business units and team members that has ensured our success this year. I believe that in difficult environments good people and good companies stand up and add value to industry. Central to this is using the power of the group and having the courage to act. The BBR Network is a powerful group full of innovative and technical minds – there is a terrific opportunity to further leverage the power of the group to own and capitalize on an ever-changing environment. As a member of the group since 1961, we look forward to building on the partnership and owning changing environments together. ●


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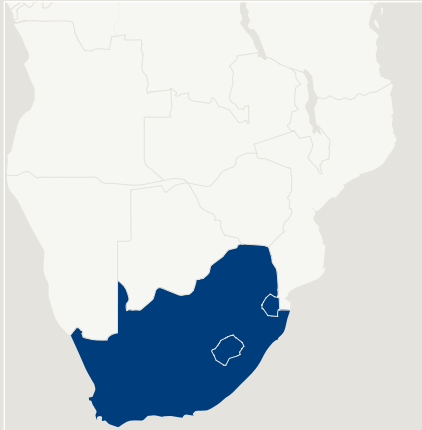
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