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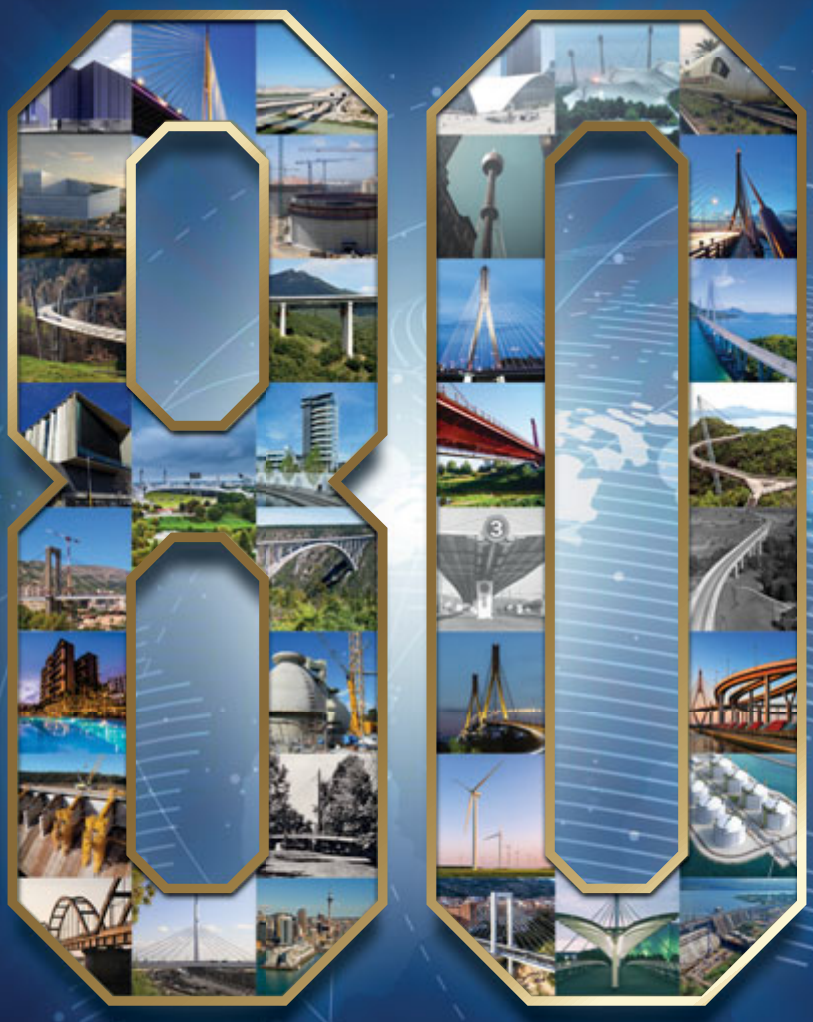
THE MAGAZINE OF THE GLOBAL BBR NETWORK OF EXPERTS



CELEBRATING 80 YEARS

SINCE 1944

BBR NETWORK MEMBERS WILL PROFIT FROM THE NEW SUSTAINABILITY PARADIGM

BBR VT International Honorary Chairman Bruno Valsangiacomo lays out a new paradigm for the next 80 years

EVOLVING OUR SOLUTIONS WITH AQUILA INSPECTION SERVICES

Introducing AQUILA and new Network Members

DOING MORE WITH LESS

80 years of enabling inspired design while reducing materials

NOT EVERY TANK IS CREATED EQUAL

Selecting post-tensioning technology strategies for tanks and silos

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 Roš – continues, now marking its remarkable 80th year, 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 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 the transfer of technical know-how.

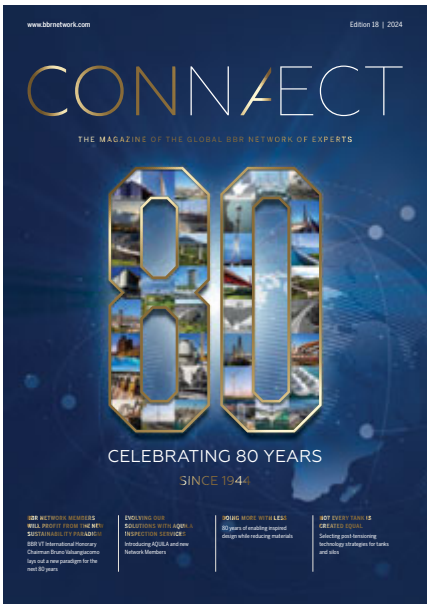
ACTIVITIES OF THE NETWORK

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 spans exactly 80 years, the BBR Network is focused on constructing the future with professionalism, innovation and the very latest technology.

BBR VT International Ltd is the Technical Headquarters and Business Development Centre of the BBR Network located in Switzerland. The shareholders of BBR VT International Ltd are BBR Holding Ltd (Switzerland), a subsidiary of the Tectus Group (Switzerland) and KB Spennteknikk AS (Norway), a subsidiary of the KB Group (Norway).



We build and we care. Constructing, perfecting and inspecting our clients' built world

CONNÆCT is our showcase to the world; a platform through which we share the benefits of BBR's technology with our clients, our internal and external stakeholders, and wider society. In this year's edition, we celebrate 80 years since BBR was founded and explore how the challenge of reducing materials remains. We highlight the exciting opportunities to build, care for and enhance the value of our clients' built assets as part of a new future we are already making.

When we started planning CONNÆCT back in August 2023, we asked: what will make the 80th anniversary issue special, in a year of celebration? One of the first ideas was to make sure that we showcased the holistic nature of our construction solutions, spanning not only many applications, but also the built asset life cycle, from design through to decommissioning. We also wanted to demonstrate, through projects from all our Network Members, how we construct and protect built assets, perfecting them with advanced solutions, like our anti-corrosion technologies, and world leading ground anchors.

In the following pages you will find projects about bridges, buildings, geotechnical solutions, special applications, tanks, and maintenance, repair and retrofitting (MRR) projects, highlighting that BBR designs, constructs and commissions.

Next, we asked: how can we celebrate 80 years of this incredible brand and the technology that underpins it? BBR was founded by three exceptional entrepreneurs, engineers and pioneers. Their legacy has been evolved by the people who made the BBR of today, who continue to build the brand and represent our exciting future. How can we celebrate this legacy? Well, we spoke to 'The Pioneers' – nine of the engineers and entrepreneurs who built, and continue to build, much of the Network we see today, a Network that serves clients in over 50 countries.

We continue this theme in a different kind of technology section, where we reveal the source of the technology alongside fascinating archive materials, and how this has enabled architects, designers and engineers to make possible what was previously impossible. Additionally, our research and development team share future technologies. The theme of materials reduction still runs strongly through our technology. You will also find our regular departments with news of the BBR family across the world. We celebrate our awards winners and provide insight into the latest member of the Tectus Group family, AQUILA Inspection Solutions.

Finally, we asked, what of the future? Surely BBR is as much about what happens next as what happened before? To answer this, we invited Honorary Chairman Bruno Valsangiacomo to share his vision of a new sustainability paradigm and how this will benefit all BBR Network Members. Our CEO, Olivier Forget, also describes an exciting new strategy that will take us securely and profitably into the next 80 years, explaining how BBR will build and care for our clients' built assets in the future.

Marcel Poser
Chairman, BBR VT International Ltd.

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Portfolio section
Tracking success in Singapore:
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BBR VT International Honorary Chairman Bruno Valsangiacomo lays out a new paradigm for the next 80 years.

BBR Network Members will profit from the new sustainability paradigm

In BBR's 80th year, BBR's Honorary Chairman Bruno Valsangiacomo discusses the new paradigm of built world ownership, and how post-tensioning reduces CO_2 to maximize asset value for owners and stakeholders alike.

The world has changed and so must we. Understanding what drives value for asset owners and their decision making must drive our approach.

Our new sales pitch is a value proposition, not an engineering solution.

"BBR must learn how asset owners and related stakeholders tick and what their value drivers are. It is not our engineering technology that's of interest to our final customers but what kind of shareholder value they will end up with. The CO_2 effectiveness of our value proposition is a key driver of shareholder value."

Bruno Valsangiacomo,
BBR VT International Honorary Chairman

During the last 80 years, BBR has built many of the world's most iconic structures using post-tensioning (PT). At this time in our history, a new property paradigm is emerging: the sustainability of a structure is driving asset and shareholder value.

The world is changing, so we must change our approach. We are no longer selling sophisticated engineering solutions to asset owners; we are selling asset owners a value proposition. This requires an understanding of what drives the most value for the stakeholders in built assets.

For 80 years BBR has built nearly every kind of structure that can be built on this planet, but we have historically not marketed and priced the CO_2 effectiveness of our construction technologies.

A sophisticated construction and engineering commodity has become a CO_2 game changer for buildings. We have the solution, but we have never marketed and priced the CO_2 effectiveness of our construction technologies.

To take advantage of this new sustainability paradigm means BBR must learn how to sell it. As part of that process, we have to get closer to the ultimate decision makers. Firstly, we sell the CO_2 value creation proposition, then the engineering solution. ›

Understanding asset owners' value drivers

BBR launched its PT technology in 1944 when the Second World War was causing massive shortages in construction materials, especially cement. The value driver for asset owners then was material efficiency – how to do more with less.

In 2024, while PT technology remains a sophisticated construction and engineering technology especially in infrastructure, it has become a potential CO_2 game changer for buildings. This is because our PT solutions are 50% more CO_2 effective than traditional construction methods. Today, the value drivers of asset owners include CO_2 efficiencies that lead to shareholder value.

The built world is responsible for around 40% of annual energy related CO_2 emissions, with embodied carbon expected to be responsible for around half of total new construction emissions between now and 2050. Embodied carbon is the carbon locked into a built asset, mainly upfront during the building phase. This includes steel, rebar and cement. There is a huge opportunity to reduce CO_2 and at the same time create monetary value for asset owners and their stakeholders, such as investors, banks, and tenants, and the CFOs and CEOs who make and implement building decisions.

Decision makers will choose CO_2 efficiency every time

How does this work in practice? Consider an international hotel group having the choice of two hotels at the same location, with the same features, but one is renewably powered by solar panels and heat pumps and built using PT. The other is built in the traditional way with non-sustainable features. The choice between PT or the traditional approach, much like the energy sourcing, is driven by the CO_2 KPIs of the many stakeholders in the hotel, and indeed any built asset. For every stakeholder, there is a benefit if the asset uses less CO_2. Here's why:

- The owner enjoys the green premium on the value of their asset.
- The investor or bank financing the asset will have its own sustainability KPIs.
- Data shows younger employees are increasingly selective about who they work for, preferring employers who share their environmental values.
- Customers freely choose to pay a premium to enjoy the services of a low carbon business. They'll pay more for a green hotel room.
- Insurers with extensive CO_2 KPIs are choosing not to extend cover to polluting industries and players if they won't change.

In the context of the above, the more sustainability boxes the hotel operator can tick, the larger the shareholder market value. The CO_2 premium becomes a force multiplier. Attracting employees with green values means a wider and deeper pool of motivated skilled workers. Lower financing and insurance costs means more to reinvest and higher profits. It becomes a CO_2 PT value creation flywheel. In reality, there is no other choice for a hotel operator than to choose the CO_2 efficient property, as shareholder value is at stake.

When you look at a multi-billion-dollar property portfolio, the why for the client, their investor and their other stakeholders, becomes even clearer. A $20 billion real estate investment corporation might have an EBITDA multiple of 11 or 12 in an industry with a benchmark of 10. This 20% of additional asset value comes from ticking all the CO_2 KPIs and means a green premium in the billions of dollars. BBR must get closer to the decision makers and sell more than an engineering solution. We must sell the CO_2 value creation proposition that increases asset values and shareholder value.

Emirates Towers, UAE, the iconic luxury business hotel found in the heart of Dubai's business district, equipped with BBR's PT technology.

The Khurais Hospital in Riyadh is a former hotel being repurposed. The structure, including floors, needs strengthening using multiple BBR PT MRR solutions to accommodate this change of use. External PT strengthens floor slabs to take the weight of hospital beds and equipment. You can read the full story on page 82.

Understanding that a built asset's health creates value

The longevity of an asset creates monetary value. This is also related to CO_2. The longer an asset can be operated, the longer the structure's embodied carbon remains locked up – demolition and new build generate huge quantities of CO_2. Understanding and communicating the value of embodied energy is part of the value proposition for asset owners.

Operating a built asset for longer requires an understanding of its health status – you need to know what you have. The construction and real estate sectors have been behind other industries in digitalization and health status inspections, but are catching up. To create digital health records and use them to show asset owners the impact on value, we must:

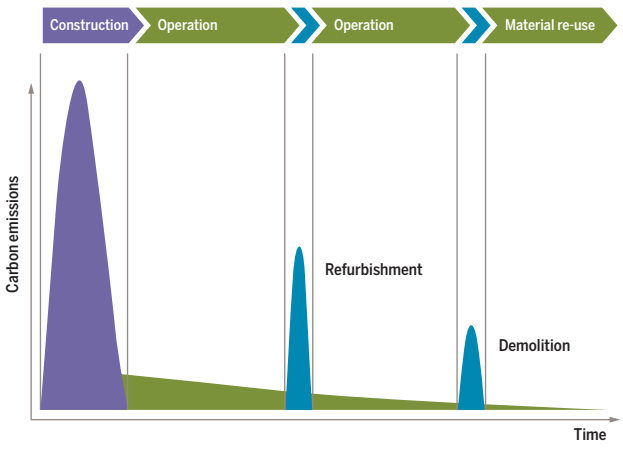
1. Be able to inspect the asset (perform a health check).
2. Assess and determine the condition (establish a health record of the asset).
3. Interpret the data, monitor and maintain the asset (decide on and perform asset care).
4. Understand the financial impact of the health record for the asset owner (informed and holistic asset management for value maximization).

Delivering all the steps in this process needs additional technologies and solutions beyond BBR's PT. Tectus Group's Screening Eagle has one of the world's most expansive portfolios of non-destructive testing (NDT) devices. NDT devices use sensors, data and AI to inspect, assess and predict the health of structures.

Inspect to protect and preserve built assets

AQUILA completes this value proposition portfolio. AQUILA inspects, processes, digitalizes, analyzes, reports and records everything to a rigorous standard and applies Screening Eagle's unique NDT and other technologies, such as drones and ground-penetrating radar. AQUILA's technologies have been extensively trialled in Singapore to assess building health, and in Saudi Arabia for MRR. You can read more about AQUILA on page 28.

From the digital health record, the asset owner can understand what is needed to maintain the asset and extend its life, which could include repurposing. This adds BBR's expanding MRR portfolio of technologies to the value proposition for the asset owner. In many developed economies, MRR accounts for over 50% of construction activity. You can learn about our latest MRR projects on pages 74-83. ›



Embodied carbon shown over the built asset lifecyle – construction, refurbishment (which may happen more than once) and demolition.

Independent research confirms PT lowers carbon and increases asset values

As greenwashing has become more pervasive, asset owners and investors hire sustainability audit firms to certify environmental claims. Buying a few trees and installing solar panels will not add to asset values.

BBR and Tectus Group have completed extensive research into how using PT technology reduces CO_2 and the impact this has on built asset values and investment returns. Independent research by CBRE, EY and JLL and other credible organizations also supports how green buildings are associated with higher asset values and increased returns.

This evidence forms an essential part of our new approach and sales pitch to asset owners. It shows we understand asset owners' value drivers. We are creating a research and communication module for BBR Network Members that will include the research reports, case studies and training.

Tectus Group commissioned independent research by Terrascope that showed CO_2 savings of up to 50% in upfront carbon for built assets constructed using BBR's PT technologies and Moderna Homes' steel-hybrid prefabricated prefinished volumetric construction (PPVC) systems, when compared to traditional rebar and concrete.

Changing our approach and message for new audiences

BBR is talking to new audiences, the asset owners and investors. When we understand what is driving value for asset owners and other stakeholders, our approach to how we sell our PT technology fundamentally changes. It is not just a sophisticated technology solution we sell, but also CO_2 reduction and asset value increasing value proposition. When we share this new paradigm with asset owners, we're no longer talking to engineers, we are in front of CEOs and CFOs who understand the drivers for creating or destroying shareholder value. They have stock options that appreciate or depreciate in value based on the share performance. To speak credibly to the CFO and CEO of the asset owner, we have to understand the fundamentals about what drives value.

We must gain access to the asset owner so we can pitch BBR's value proposition directly to them. This means having an early role in the design process. Usually, when we get involved, the architect has already completed the design and then BBR proposes an alternative PT solution. Moving forward we should approach the asset stakeholders early, explaining to the architect that we can plan a joint approach – together we'll propose a skyscraper saving 50% of the embodied carbon compared to traditional approaches.

Our joint proposal will of course highlight the architecture, the iconic design, the elegant construction solution, the sophisticated PT technology, and the cost. But we will focus on the benefits of the CO_2 values compared to other approaches and what that means for KPIs and shareholder values. We can share the Tectus Group, BBR and Terrascope research and data that clearly demonstrates how asset owners benefit. This increases the chances of winning the project, with an improved price, because of who we speak to and when in the process.

Expanding our work into new markets

BBR Network Members are market leaders in designing and constructing infrastructure for public sector clients. This is important work that benefits society. But the timescales of public sector work are often only as long as the next electoral cycle, and there are fewer drivers to increase asset value by reducing CO_2.

Asset owners of commercial real estate investment portfolios think both short term for the markets, but also long term for shareholder value. They want retail, office and residential investments, and private utilities and energy projects, to deliver above market return, that meet CO_2 reduction KPIs and which increase shareholder value. High rise buildings with less rebar and concrete are built faster so they start generating rents sooner with less CO_2.

Based on a 2022 study completed by the CBRE of 20,000 office buildings, average rents of those with LEED* certification are 31% higher than those of non-LEED-certified buildings.

*** Leadership in Energy and Environmental Design, US Green Building Council**

PT becomes the only value creation show in town

A CO_2-driven boost of PT use in buildings drives up demand across the industry. As we grow our capacity, PT resources will be in short supply. In turn, this will result in higher PT prices. However, the key point is not whether PT can be price competitive versus traditional methods. The traditional approaches cannot deliver the CO_2 savings, so they cannot provide the higher asset values and greater shareholder value. It is no longer a competition because traditional approaches don't qualify. If we understand this value creation effect and impact, and if we learn how to tell the story to the decision makers as part of our new approach, we will offer 'value creation pricing' to our clients.

Now is the time to adopt the new paradigm with a new strategy

To all the asset owners reading this, I say you can choose a proven and certified technology that has successfully reduced carbon for 80 years to achieve your CO_2 reduction KPIs. A value proposition that is up to 50% more effective in embodied carbon than traditional approaches and does not need distractions like solar panels that only last a few decades. We can create massive value for all your stakeholders.

To our valued Network Members, in BBR VT International CEO Olivier Forget's business review on page 18, he introduces BBR's strategy to build on the last 80 years of success. This strategy has evolved to align with our new paradigm, harnessing our CO_2 reduction value proposition to target asset owners. Olivier shows how we will pivot the value chain and move into parallel verticals, so we are in front of the decision makers with a value proposition they will understand.

A BBR operative is using Screening Eagle Technology to inspect a building, uploading it to AQUILA digital health record platform, to share with the asset owner.

80th anniversary special
The Pioneers who grow and shape BBR globally

THE PIONEERS

The whole is greater than the sum of its parts

BBR was born from the vision of its three founders, Max Birkenmaier, Antonio Brandestini and Mirko Robin Roš. These pioneering engineers and businesspeople gazed upon the shattered post-World War Two landscape and saw an opportunity to rebuild with a unique post-tensioning technology. Since that day in 1944, BBR has undergone a global expansion fueled by the vision, passion and expertise of dozens more engineering and business pioneers.

In memoriam: Fritz Speck

There is a tenth pioneer who, according to the Network Members interviewed, played a huge role in growing and guiding BBR during his tenure as CEO – Fritz Speck. Sadly, Fritz is no longer with us. However, his legacy keeps his memory alive in the minds and actions of the pioneers who knew and benefited from Fritz's encouragement. ›

In 2024, 80 years after BBR's founding, the latest pioneers from the UK and the Netherlands have recently joined the BBR Network. They, like other new Network Members before them, have been inspired by the same vision as BBR's founders, recognizing the opportunities post-tensioning technologies offer to those who see them and how they can benefit society.

So, what makes a BBR pioneer? We spoke to nine. Seven of these explored new territories and two supported and guided them, as well as pioneering the unique Network membership model of BBR VT International today. We asked what inspired them, the challenges they faced and overcame, and where their journeys have taken them.

Throughout these hour-long interviews, five themes came up again and again. Interconnected, they reflect the core values of what makes BBR and its Network Members successful.

Vision

The enduring 80-year success of BBR has been led with vision, first by the founders in 1944, then by their successors in Switzerland and throughout what was to become the global business and the BBR Network. Each pioneer had their unique vision for their market and territory, and BBR's leadership shared and supported it as they developed the BBR brand, its technology and business model.

Within some new BBR markets, realizing the vision required patience. Jan Piekarski, co-founder of BBR Polska in 1993, explains: "After years of economic crises, Bruno [Valsangiacomo] was a visionary who trusted in Poland. He believed economic development would follow when the Wall came down."

Jan says this optimistic vision of Poland's potential was shared by Antonio Brandestini, one of the original BBR founders. "That made it impossible to disappoint," jokes Jan. The third believer in Poland's potential was Fritz Speck, BBR's CEO in the early nineties. BBR Poland took two years to win its first significant project. Now, 30 years on, BBR Polska is Poland's leading PT company.

28 years later, in 2019, the vision of BBR Saudi Arabia's founder and chairman, Nghaimish Alharbi, came to fruition more rapidly. He saw PT technology as the alternative to all reinforced concrete (RC) solutions across the Middle East, not just PT competitors. But only 14 companies had adopted BBR Saudi Arabia's PT solutions. He elaborates: "PT held a 2% share of the Kingdom of Saudi Arabia's (KSA) market for concrete solutions. We targeted the decision makers in the supply chain and concentrated on educating consultants and architects about the advantages of PT over RC." His vision was echoed by Bruno, who visited in September 2022 to discuss new technologies (further details below). By 2024, through the dissemination of his vision, Nghaimish and his colleagues have sold BBR solutions to numerous companies and successfully completed most of the iconic projects.

Pivot to Asia and the theme, if not the challenges and opportunities, were similar. Voon Yok-Lin was a founding partner in, and is current managing director of, BBR Construction Systems in Malaysia. He and co-founder Andrew Tan, CEO of BBR Singapore, both had long associations with PT in other roles. Voon notes that Malaysia in the early nineties was undergoing an infrastructure boom as the economy accelerated and Andrew knew PT as a highly effective "build faster, higher, safer" solution that offered good value for clients. Supported by Bruno and Fritz, the BBR Malaysia vision crystallized quickly for Andrew and Voon. With support from BBR Singapore and BBR in Switzerland, the company played a foundational role in the new 1994 transit system. Then in 2004, BBR Malaysia gained a high profile as a bridge builder following work on the bridge linking Sarawak and Brunei, then the country's longest.

Since 1944, meanwhile, BBR in Switzerland has employed a number of business models in its global operation. These include wholly owned subsidiaries, local licenses and equipment purchases. In the nineties, the changing world presented new opportunities and risks. So, when the business passed onto Bruno in 1996, he introduced a fresh vision for future global expansion. This was charged to his new appointees, Fritz Speck and Pietro Brenni. And, in 2002, Pietro hired Marcel Poser as CTO, giving rise to the vision of the BBR we see today.

After wryly noting he recalled organizing BBR's 60th anniversary in Zurich in 2004, Pietro—BBR CEO from 1999 to 2006—explains that during the mid-to late-nineties BBR went through a period of technological improvement and built a global direct contracting business: "There were new European Technical Assessment (ETA) requirements, and we needed a business model so our licensees could participate in the resulting technology updates. At the time, the company was more oriented to establishing companies in different countries where licensees were not present and delivering its own contracting business. Contracting has a risk. So, in 2000, we decided to step back and to focus more on BBR updating the technology and providing it for the licensees to use." This simple phrase only hints at the major re-visioning and strategic analyzes that Pietro drove in the early noughties, working with shareholders to reorientate BBR.

Marcel, former CEO who returned as Chairman of BBR VT International in April 2024 after a sabbatical, takes up the story: "BBR's focus on sourcing technical knowledge leaves execution to the franchisees, simplifying the business model and relationships. The focus on technology by this newly focused center, BBR VT International, meant we could introduce additional shareholders, large international construction and engineering brands. The result was providing the franchisees, our Network Members, with all the benefits of a major international business for sourcing and approvals, without their being owned.

When Pietro took on his family business in 2006, Bruno appointed Marcel as BBR VT International's CEO to create the network and its infrastructure. The outcome of Bruno, Pietro and Marcel's vision, alongside the market-focused visions of all our pioneers, gave rise to the current BBR.

Technology

Technology gave the founders their competitive advantage in 1944. It may have been refined and expanded significantly over 80 years, but it's still at the core of the BBR brand and its Network. It was the technology, its applications and the ultimate societal benefit that inspired our pioneers. PT enables features and applications that are difficult and expensive or simply not possible with other technologies.

Paul Wymer, former Managing Director of Contech, BBR Network Member for New Zealand, says his country was one of the first outside of Europe to open a BBR business, BBR NZ Ltd. Operations commenced in 1963, he says, supported by two "ambitious and driven characters", Rob Irwin and Rob Robinson. Rob Irwin had gained a deep understanding of PT while working in Switzerland and he returned to New Zealand to develop the use of the BBR technology and build a local team. "New Zealand has always been an early adopter of technology and is known as a place where new ideas get started. It is a great test bed. We had a need for new technology to support a surge in road and railway infrastructure at that time and PT reduced steel and concrete use. It had an elegant efficiency for creating structures."

Paul Wymer

BBR was first introduced to France in the sixties by the Boussiron company, when civil engineer Nicholas Esquillian designed several iconic structures using BBR PT technology. These included Le CNIT in La Défense, Paris, the Rhône rail crossing at La Voulte, near Lyon, and Marseille Provence Airport. Several changes of name and ownership led the formation of ETIC by Claude Néant, with two colleagues, the French licensee of BBR technology. His knowledge was already deep for, as a young engineer, one of his early roles was precisely calculating PT and stay cable lengths before on-site installation. The original BBR solution Claude licensed was a wire systems technology, then adding PT solutions as the BBR range gained increasing French and European certification through fatigue testing. "BBR was a well-known PT supplier in France after BBR PT solutions were installed on several high-profile bridges, including the A40's Viaduc de Sylans and Viaduc des Glacières, at Roissay Airport and in the Bugey Nuclear Power Plant."

Claude Néant

Technology and the BBR brand also helped BBR Malaysia move quickly and win early bids on the Asian country's growing transit systems. "Having been established in 1944, with a 50-year history and the globally recognized ETA certifications, the BBR brand was easier to launch in Malaysia," says Voon. "Also attractive to the original transit system client was BBR's experience, not just local but international experience."

Yok-Lin Voon

Although PT was readily accepted and acknowledged in New Zealand, France, Malaysia and many other countries, this wasn't true in Poland. According to Jan, back in 1993, when he first launched what was to become BBR Polska, Polish PT was in crisis: "Despite being taught at university throughout the 1960s to 1980s, years of centralized Soviet planning and a focus on steel had removed the approach from Polish engineering," he explains.

A similar challenge faced Želimir Bodiroga in the Balkans. The founder and CEO of BBR Adria, the BBR Network Member for Croatia, Bosnia & Herzegovina, Kosovo, Montenegro, Serbia and Slovenia, once worked for an architect in Berlin. While there, he learnt about BBR technology's applications from Pietro and Fritz. "Years later, I returned to Croatia and saw that PT was not being used to benefit projects in the country despite the technology's huge potential in areas like hardening buildings against earthquakes and repairing them afterwards. So, I contacted Pietro."

After founding BBR Adria, the lack of PT knowledge meant he needed a penetration strategy. "I asked myself, how can PT technology be introduced to my local market? It started by winning over a Swiss designer working in Zagreb, which led to our first project, a car park." Long term, Želimir has invested in educating young engineers, like his 30-year-old self when first introduced to PT.

Nghaimish recognized that while the benefits of BBR's PT technology would eventually drive product sales, he needed to give it a jump start. While educating designers about the advantages of PT, he quickly identified a strategy to outperform RC solutions: addressing complexity. "We changed tactics by intentionally selecting a consultant with a wealth of projects. We pursued challenging projects with intricate designs, offering solutions to the engineering challenges faced by clients. We are competing based on the engineering excellence of BBR technology and its certifications."

Opportunity

With world-leading technology giving competitive advantage and a vision to exploit it for societal good and to grow a business, another key ingredient for success is opportunity. This is another unique skill of the pioneers: the ability to meet local market demand with the right solution at the right time. This is supported by the BBR Network's outstanding knowledge of regions and their particular culture.

Želimir doesn't believe it's possible to grow in new markets without this understanding: "Although always there to provide support, Bruno, Fritz and Pietro gave me free hand to take decisions in my market. Croatia is not Germany. Many Swiss and German companies try to copy and paste a new business from their region. ›

That's one of the best ways to destroy a business." Local knowledge, focusing on a region's specific needs and extending this approach to other countries led to BBR Adria's expansion across the Balkans.

Želimir Bodiroga

In New Zealand, the initial opportunity was investment. "Before the early sixties, New Zealand did not have a track record of delivering large projects," says Paul. "But it happened to be around that time that some significant road and rail infrastructure projects, and other civil engineering projects like dams, were commissioned." BBR had a strong brand already and was scalable, enabling fast, high-quality construction.

It was similar for Voon in Malaysia. He launched a local business that benefited from a globally recognized brand and world-class certifications at a time when infrastructure investment rose sharply. But that wasn't the only opportunity. "Many designers would shy away from PT, viewing it as too tedious because there was no user-friendly computer software, so we promoted PT to the architects and owners designing and constructing buildings."

Andrew notes that local knowledge and identifying opportunities led to BBR Singapore's growth and expansion into Malaysia in 1994 and the Philippines in 1998: "Singapore experienced a rapid phase of development in the 1970s, an opportunity for the original BBR Bureau. It was easier to open doors in neighboring countries as most used UK standards, many engineers spoke English having been educated in the UK, so they were familiar with European codes and systems."

In contrast, Jan's new business had to navigate minimal available investment in the immediate post-Soviet era. And at one point, the Polish inflation rate rocketed to 80%. One of the factors that made a difference was Jan's decision to launch and staff a local company and not just a sales office. This demonstrated commitment and confidence in the future Polish economy at a time when competitors fumbled. It gave Jan, supported by Bruno, Fritz and later Pietro, the five years he needed to establish BBR Polska as the market leader in PT.

The recent experience of Nghaimish and BBR Saudi Arabia reflects a thriving market fueled by growth and ambition. However, projects are typically awarded based on price rather than value. This paradigm is gradually shifting, and Nghaimish seized the opportunity. He explains: "I believe engineering is the key differentiator. By educating and collaborating with consultants [designers] who typically prioritize business generation over design, we offer value engineering services to new consultants. The new services introduced by AQUILA [as introduced by Bruno on pages 6-11] will further enhance this advantage."

Nghaimish Alharbi

The strength of BBR's engineering alongside partnering with local experts, and the evolution of the built world, were all behind the strategic decision to refocus the core business in 2004. This was an opportunity.

Back to Pietro: "Stepping back [from being a contracting business] and taking care of the IP was the correct approach. Controlling the technology delivers greater value. It allows BBR VT International to focus on the plant, equipment and component production quality and supply chain, certifying the source of materials, not just protecting the IP and developing the technology." This allows the Network Members to focus on their markets and clients.

Collaboration

When it was envisioned by Bruno, Marcel and Pietro and colleagues in the noughties, the BBR Network as a franchise concept was unique in the global engineering world. Yes, the concept of licensing and exploiting technology for local markets has worked well for centuries. However, the unique technology licensing and supply, territory allocation, deep technical and business support from BBR and, importantly, the collaborative knowledge-sharing approach between members is what attracted our pioneers, as they will explain.

First, Marcel highlights that collaboration needed infrastructure: "In the space of five years, from 2006 to 2011 during my tenure as CEO, we had new PT technology, new technical approvals, new sourcing, new reporting and new marketing. This was to serve new franchisees in 50 countries. In 2006, we had the first BBR Global Conference and in 2007 the first edition of CONNÆCT."

BBR was strong at collaboration even before the Network was established, as Jan highlights. He sought Network help to grow low PT knowledge in post-Soviet Poland: "We educated young engineers from the beginning with help from Switzerland and we could call and ask for advice. We collaborated with the design office in Zurich, so many Polish bridges built in the nineties and start of the noughties were designed by Swiss engineers." That knowledge and know-how sharing was transformative. Now it is BBR Polska that supports other BBR global Network Members with PT and cable-stayed bridge design...

Jan Piekarski

No matter how the worldwide business has been structured, the collaboration has been consistent, notes Andrew: "Working with support from BBR's technical team in Switzerland, engineers from European Network Members, and the network around the work means, if we encounter a problem for the first time, we have the opportunity to tap the Network in other countries for other experts who have encountered and solved it." He adds that sharing information and equipment is common.

Andrew Tan

For Želimir, its simple: "Without a good team, you can't achieve anything. Civil engineering is teamwork." He adds that BBR is very much like a family.

Since becoming a Member, Nghaimish's BBR Saudi Arabia has actively engaged with the Network. They align with his core mission of educating clients in the region: "BBR possesses a wealth of engineering expertise to share within the network, along with marketing and educational support. We also have experiences to share with other Network Members. We are delighted to collaborate with a brand that boasts such extensive expertise. Our vision is to expand into all areas of PT." Thus far, this expansion has encompassed bids for tank, geotechnical, and MRR projects, the latter in collaboration with AQUILA.

The success of the collaboration is the people; all our pioneers highlighted the importance of relationships. Paul explains: "From the early days and connections with the founders, and the people that followed like Fritz, Pietro, Marcel, Antonio, Juan and Olivier, the individual relationships have survived even when they've gone. That's a special part of BBR. It is a reason beyond its technical strength why it has survived and prospered."

"BBR is still a pick up the phone business," adds Pietro.

Cost and carbon

Today we understand that efficient materials use advances the low-carbon agenda and gets us closer to net zero, thus slowing climate change. But post-tensioning was attractive in 1944 because it meant using fewer materials at lower costs. In some cases, this was a necessity as there were not enough materials for traditional approaches.

In the days of the original pioneers "PT take-up was driven by high strength steel availability after World War Two and a lack of other materials; not because of CO_2, but efficient construction," explains Pietro. "Today, the investor and owner are prepared to pay to use the right materials and approach if they can document this [carbon saving]."

Pietro Brenni

Andrew's Singapore experience was similar: cost first, not carbon. "Bureau BBR was a specialist in PT structures, proposing that clients convert to PT using the BBR system. We offered design and specialist work to save clients money, build faster and at greater height. Carbon was not a big story."

The same was true in many markets in the early decades of BBR. Indeed, cost did not always work in favor of PT. Voon says: "Following Malaysia's financial crisis in 1998, there were not many stay cable bridges because of costs. By 2004, that had changed. PT helped to solve many difficult problems. The first land crossing from Sarawak to Brunei was a high-profile launch for BBR's stay cable systems. No-one had built spans like that before."

We quoted Paul earlier recounting New Zealand's surge in roads, railways and bridge construction during the mid-sixties…"There was a need for new technology to build this infrastructure. PT was chosen for its technical efficiency and cost effectiveness, not climate change." Fast-forward 60 years from BBR New Zealand's launch to the Network Member for New Zealand, Contech today. Alongside new build using PT, its focus is on solutions that protect, repair and restore: all low-carbon solutions.

Steel structures were one of Poland's strengths in the Soviet era. In fact, Jan met the BBR team in Switzerland while on business for the country's largest steel firm. Lower-steel PT was a useful cost-saving proposition in a nineties Poland marked by economic challenges and hyperinflation. But carbon was not part of the story. Nonetheless, recent editions of CONNÆCT feature many BBR Polska bridge building projects whose embodied carbon has been reduced by a PT solution.

Marcel Poser

During the noughties, when creating and updating BBR VT International's infrastructure to support the new BBR Network Members, Marcel's focus included sustainability as well as procurement quality, efficiency and transparency. That was a core driver for BBR E-Trace to be digital: "The question was do it analog or digital? Bruno's media experience helped. It took three developers to complete [the E-Trace platform]. It is still in place now."

Ultimately, the PT value proposition has transitioned from cost to carbon. This, concludes Marcel, is "the future" and completely fits BBR's DNA: "Building new is one thing; maintaining what we have built is key. The built world has the greatest store of embodied carbon. Our thinking must change to operating assets for much longer. The whole inspection and engineering service piece [in Bruno's introduction] is very attractive, representing a shift in value creation." It represents a perfect alignment of global society's sustainability needs, asset owners' carbon reduction, valuation needs and the commercial needs of the BBR brand and its Network Members.

This edition of CONNÆCT, and this article, celebrate 80 years of BBR. With so many pioneers contributing to this story there has been much to learn from past achievements, and challenges. What was most exciting about the many conversations we had was the way they all touched on the next 80 years. How the themes of vision, technology, opportunity, collaboration, and now carbon, have endured. Like the BBR brand, everything it stands for will endure for another 80 years, and beyond.

Business Review
Evolving our value chain – strategy from BBR VT International's CEO

EVOLVE & ADAPT

BBT VT International CEO Olivier Forget introduces a new strategy that takes the brand into the next 80 years.

80 years ago, BBR started a journey. Its three founders recognized a challenge: the societal need for a high-quality built world that used less material to reconstruct Europe following World War Two.
As we know, that challenge was met, and post-tensioning was the result. That journey continues today, yet the societal need is both the same and greater. There is now a requirement globally to construct, update and manage a built world using fewer and different materials, low or no carbon, all with greater resilience, safety and quality.

The built world runs at different speeds. Advanced economies have their infrastructure, so the focus is on maintaining, preserving and upgrading it. Growing economies need new, low carbon-built worlds. These needs are increasingly met through re-specification and the upgrade of existing assets designed for different times and extending the life of existing assets.

We have more stakeholders, having learned from Bruno in his introduction about how the future of the built world is evolving. How investors and asset owners are prizing environmental, social and governance (ESG) as well as, perhaps even more than, profit, because it enhances asset values.

Our people, and employees across the built world, are demanding change and a shift in perspective. They want a new purpose: to become contributors to change rather than polluters. We cannot attract talent or maintain our capabilities to build without altering our image. These are exciting opportunities for post-tensioning thought leaders like us.

It would not end with the tragedy that climate change represents.

This is also a shift in perspective that we must be a part of and contribute to, not only for our business to adapt to the economy but also to continue attracting talent and provide a compelling reason to join our construction industry, and for the sake of our children.

Evolving what we do and how we do it

In its 80th year, our challenge is to evolve BBR VT from its current position to become a business that will overcome all these challenges, and more. This means extending and owning our value chain across all our market verticals, evolving what we do and how we do it.

Fortunately, we are already strong and are not newcomers to change. Many times, in the past, my predecessors took bold decisions to reorient and prepare our business to overcome fresh challenges, often before the challenges and need for change were widely acknowledged. These strategies were successful there is no doubt. The evidence is a thriving business in its 80th year.

My role is to lead BBR through this next period of evolution with a fresh strategy. We will align and implement this strategy together with our stakeholders: our shareholders the Tectus Group, BBR VT's leadership and employees, our Network Members and their clients, our partners in academia and business, financiers and asset owners, policymakers, and the wider world.

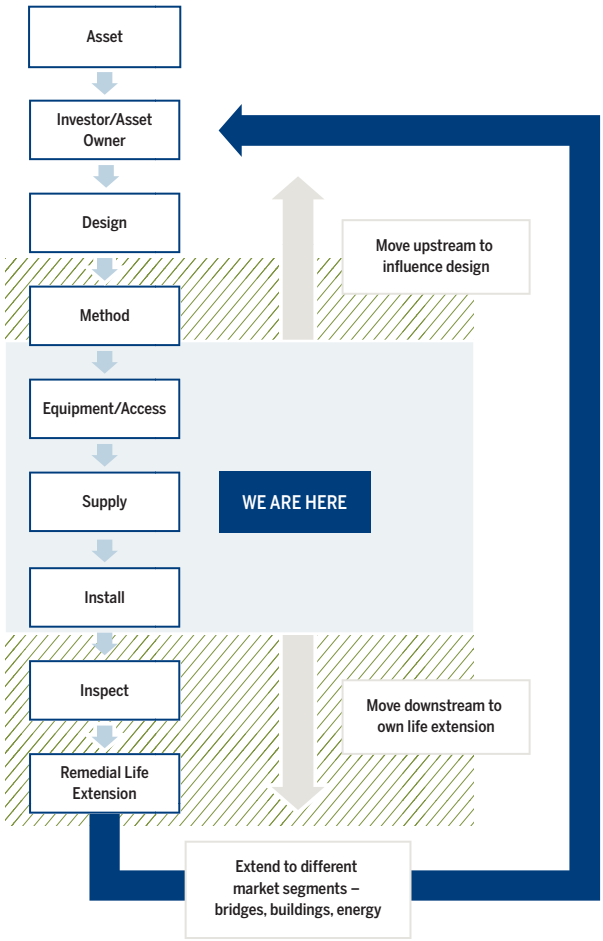
From a six-month program of stakeholder engagement, visiting each of our Network Members, closely working with Bruno, Tectus Group and our BBR VT colleagues, and with inspiration from our partners, we will evolve our value chain across four strategic pillars:

1. Market segments focus: Focused yet aligned positioning strategies for each of our four key market segments (post-tensioning, stay cables, geotechnical, maintenance, repair and retrofit, or MRR) to drive growth.
2. Expand the Network: We want all societies and communities globally to benefit from low carbon PT technologies. We want to make it possible, using PT, to build bridges, dams or wind farms that could not be built before. We need more Network Members to build market coverage, strengthen BBR brand recognition, fortify our supply chain and sustain our business model.
3. Knowledge sharing: We can enhance our strength by enhancing how we operate as a network through sharing market intelligence, differentiating factors, successes, both commercially and operationally, and achieving greater success through identifying opportunities for further development. Establishing working groups of experts will grow both our capabilities and sources of competitive advantage for all Network Members.
4. Sustain and expand services: Positioning ourselves as experts in a wider value chain with an expanded scope of work means our entire Network becomes more than suppliers and installers. We must extend our reach into designing and value engineering, promote technologies with higher standards and design life, strengthen and enlarge the supply chain of niche products, develop integrated inspection internally within the network and subcontracted, while promoting MRR solutions to extend life of existing world.

Each element of our integrated new strategy is interdependent, positioning BBR VT as the enabler for the Network, facilitating vertical development of value chains by Network Members, starting with asset owners through to MRR. We then use the value chain relationships in one segment of activity to extend the value chain horizontally into a parallel vertical segment. We can leverage the existing relationship with an asset owner, designer or contractor when building them a new asset along the value chain into maintaining their existing assets using our inspection and MRR capabilities. We can also move between verticals in the same way, from building buildings into bridges or tanks, via the same clients, designers and contractors.

The desired outcome is reducing the creation of CO_2 for new build and existing structures, increased asset value creation for our new financial and asset owning stakeholder groups, alongside sustainable success for all Network Members.

All our actions must contribute to promoting and enabling the low-carbon transition of the built world through our expertise and capabilities.



Extending our reach throughout the value chain.

Strategic pillars and action plan

Evolving our business segments

BBR VT has four market-focused business segments, each with unique opportunities to extend the value chain and product range through brand extension and R&D, evolving to meet the challenges we face. To reflect the different growth potential and barriers, we have developed a focused strategy for each market segment to extend value chains and optimize brand awareness and revenue contribution.

The post-tensioning (PT) segment includes buildings, bridges, wind turbine towers, LNG and nuclear applications. Bridges are historically our largest segment by revenue, a position to defend, with buildings a close second. We have an impressive track record and strong prospects for tanks, wind turbine towers and nuclear, with the right positioning.
The renewable energy sector is a strategic priority, as it is experiencing exponential growth, and is demanding new technologies to construct taller structures with fewer materials. This aligns with BBR VT's commitment to slowing climate change by reducing CO_2 emissions.

Our 450 stay-cable bridges worldwide contribute to bridge segment strength. As a captive market, it presents a unique opportunity to propose to asset owners that we inspect, maintain and extend the life of existing bridges, many of which are iconic, highly valued by society, and irreplaceable.

Despite its market-leading comprehensive product portfolio, the geotechnical business is underrepresented and will secure more business with investment in brand and sales infrastructure. BBR VT must now promote its pioneering offer in this sector to differentiate itself, leading to more safety in design and proven performance.

Despite Network Members' successes, **MRR** to extend asset life and values and save carbon is a relatively untapped source of strategic, long-term and repeat new work. Our brand, existing and growing product range with unique technologies to come, including integrated inspection solutions, partnerships and positioning, will unleash MRR's potential.

OUR PRIORITY ACTIONS

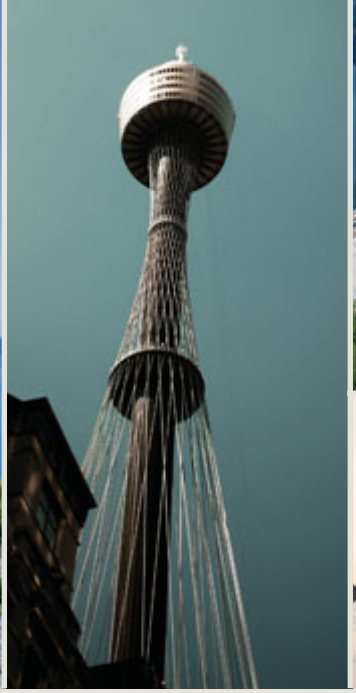
- Extend the value chain in buildings and sustain bridges and stay-cables, promoting advanced solutions like EIT.
- Develop upstream positioning in energy, such as sharing or owning the design stage with tanks and silos for energy storage, and establishing partnerships from design stage for hybrid wind turbine towers, and "premium" PT for nuclear.
- Invest in brand awareness for market credibility and sales, alongside the internal supply chain in geotechnical, thanks to our existing Network Members active in geotechnical, and supporting new entrants from the Network.
- Leverage brand, product portfolio and Network know-how to secure greater MRR market share, working with designers and asset owners. This approach can be applied to all countries with aging infrastructure and can also be proposed as a solution to prevent or preserve and repair after natural disasters such as seismic events.

Evolving our Network

We are successful together. BBR VT enjoys a symbiosis with our Network Members across the globe. But our Network does not yet extend enough across the globe. There are many countries that do not gain the benefits of PT and lower carbon structures, of the preserved and resilient buildings. With fresh Network Membership agreement models, we have a global strategy to extend our reach through existing and new Network Members in Europe and Asia, then Central and South America and Africa. Growth is equally important for our existing Network Members. Our Network strategy includes additional support for our current partners to maintain BBR's international recognition, sustain our supply chain, address challenges and grow their business.

OUR PRIORITY ACTIONS

- Reactivate existing contacts with greater agility and flexibility, providing bespoke access to technologies, enabling a win-win scenario through step-by-step approaches.
- Invest in market research and networking in strategic geographical markets to onboard new Network Members.
- Grow support for our existing Network Members with a customized diversification plan tailored to each market segment; through extending agreements with specific new MRR solutions, to develop inspection and geotechnical Network membership. Not all Network Members can or should deliver all BBR solutions in every location. Solutions must be proposed and tailored according to the preferences and capabilities of each member, applying a flexible and collaborative bespoke approach.
- Our approach will be global access to cutting-edge BBR technologies, combined with a flexible locally tailored solution for each Network Member.



Evolving our knowledge

Together, BBR VT and Network Members represent a repository of knowledge gained from over 80 years and 2,500 PT projects. When you add our lead shareholder Tectus Group and its other brands, like Proceq, Screening Eagle Technologies and newly launched AQUILA, our access to technology and expertise – and the competitive advantage it represents – is immense and unique.

Leveraging and sharing this resource to increase our Network Members' successes and to extend our presence across the built world value chain is our priority. If our Network is not successful, our business model is not sustainable. It is a rather simple equation: our success relies on the success of our Network, its capabilities to find and secure projects, to contract and perform.

There are more synergies between BBR VT and the Network to be realized. BBR VT has its history, core business and wider group capabilities, the Network brings many local capabilities and wider expertise. For example, we aim to develop a design hub service that centralizes existing Network Member capabilities in our Buildings sector. The Buildings Hub will be available to the entire Network and to new members on commercial terms. For Bridges and Geotechnical, we aim to elevate standards with the invaluable expertise of some Members. Similarly, for Tank and MRR projects, we not only prioritize technology but also emphasize value engineering and leveraging the expertise of our Network Champions. BBR Network Members are the local roots who contribute their strength to the global BBR Network.

At every touchpoint, we will engage with and educate the decision makers behind the built world about how PT solves their challenges. Financiers, investors and asset owners will learn how our approach will increase their built asset values.

OUR PRIORITY ACTIONS

- Develop the network with an agile, flexible, bespoke and win-win approach.
- Continue driving our technology portfolio development to meet the needs of all segments. It is in BBR's DNA to be innovation champions.
- Create expert working groups that benefit both the contributors and the Network.
- Build a design hub to benefit existing and new Network Members.
- Educate the upstream value chain—including architects, asset owners, banks, and investors—about BBR's contribution to reducing carbon emissions in both new construction and existing buildings.

Evolving our services for competitive advantage

BBR was created 80 years ago by our founders who innovated to meet a societal need. Constantly evolving and innovating our technology underpins our, and each Network Member's, success. Our technological evolution must – and will – meet the societal needs and challenges we face today.

We have multiple R&D programs in progress across our core PT, stay-cable, geotechnical and MRR technologies to ensure we remain competitive and relevant, as well as compliant. To support the manufacturing and distribution of our technology, ensuring our Network has quality equipment on time, to specification and in full, we have supply chain projects underway. These include a second supply chain center in India, additions to our approved supplier base, and a sustainable isupply chain in Europe.

To address how our built world is changing, and to support the expansion of our MRR PT technologies, we are creating MRR solutions and an integrated inspection service. In addition to new MRR technologies, this inspection solution will empower Network Members to own more of their downstream value chain.

OUR PRIORITY ACTIONS

- Progress R&D projects in business segments and technology streams.
- Deliver planned enhancements to the supply chain.
- Grow MRR technologies and integrated inspection solution so it becomes a stand-alone and valuable business segment for Network Members.


News in brief

Overview of events and achievements from around the BBR Network

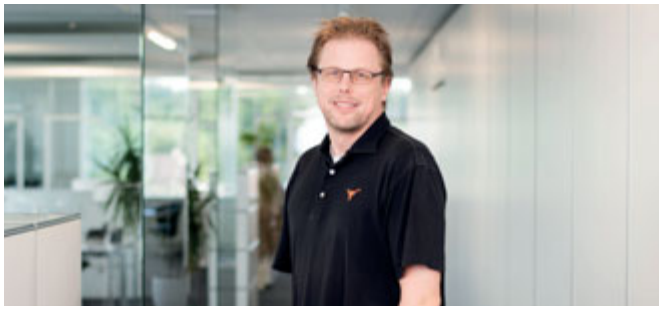
2023 has been a memorable year for BBR VT, with Network Members taking the brand to Poland, Morocco, Singapore, and France. As we celebrate our 80th year, we have also strengthened our management team and board as a foundation for future growth. Meanwhile, new resources on the website have supported Network Members both in sales and operations.

LEADERSHIP CHANGES PROMOTE CONTINUITY AND GROWTH IN 80TH YEAR

As BBR enters its ninth decade, we've strengthened our leadership team and board with experienced appointments which prioritize experience, growth and innovation. Beat Joss joins us as Senior Business Development Manager with 23 years in post-tensioning, heavy lifting, and repair work. Baran Kurutepe, as International Business Development Manager, will leverage his 20 years in construction and cable-stayed bridges to expand BBR VT's reach in central Asia, north Africa, and the Middle East.

Dr. Haifeng Fan, meanwhile, with seven years at BBR and a PhD from EPFL Lausanne, becomes Head of Technologies. Marco Corti, after six years with us, takes charge as Head of Supply Chain. Gianni Moor, possessing over 25 years of international management experience, joins our Board of Directors, also representing the board on the executive team. Bruno Valsangiacomo transitions to Honorary Chairman. Former Chairman and CEO Marcel Poser resumes the Chairman role.

We congratulate our newly promoted team members and extend heartfelt thanks to outgoing Daniel Cuerdo and Behzad Manshadi for their contributions to BBR VT.



Marcel Poser returns to BBR VT International as our Chairman.

NETWORK MEMBERS CONVENE IN POLAND FOR WORKSHOPS AND BRIDGE VISIT

In October, BBR Network Members traveled to Warsaw, Poland, for workshops on the latest developments at BBR headquarters, innovations in BBR's geotechnical products, including the new BBR VT CONA CMG system, and advancements in BBR's post-tensioning and stay cable systems, specifically the BBR VT CONA CMX.

During the event held between 10th and 12th, attendees visited a construction site with BBR Polska to view work on the A2 motorway Warszawa Kukuryki bridge. They also watched a presentation on the project sited just 6km from the Belarussian border.

Workshops were held on the latest in BBR's post-tensioning and stay cable systems, specifically the BBR VT CONA CMX.

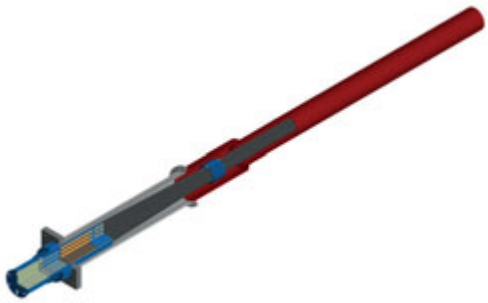
BRIDGE SITE VISIT A HIGHLIGHT OF EUROPEAN BBR PM'S WORKSHOP

In October 2023, members of the BBR Network visited BBR Polska's A2 motorway bridge construction site. Trainee delegates examined the important crossing that will facilitate travel between Poland and Belarus. The inspection of the Warszawa Kukuryki bridge just 6km from the Belarussian border, was a key activity during a three-day training event focused on post-tensioning technologies. During this event, the members also received updates on the latest developments at BBR headquarters, innovations in BBR's geotechnical products, including the new BBR VT CONA CMG system, and advancements in BBR's post-tensioning and stay cable systems, specifically the BBR VT CONA CMX.

Network Members tour BBR Polska's post-tensioning work on the Warszawa Kukuryki bridge.

DRIVE MORE SALES WITH UPDATED CONA BROCHURE AND PROJECT FINDER

This year, we added two must-have resources to our (already invaluable) BBR website.
The totally revamped BBR HiAm CONA strand stay cable system brochure has been designed to support your sales team. It includes new information and sections about testing compliance with *fib* Bulletin 89, the adjustable Pin Connector, the HiBox Saddle, and an overview of complementary technologies. We've also added a chapter on inspection, maintenance, repair and retrofitting.
Meanwhile, the Project Finder contains essential information to help sales to match potential customers' needs with previous successful applications of BBR's post-tensioning technology. We've updated stay cables with new projects while LNG/LPG tanks projects have had a content and design update to make them more accessible for everyone. You can access both at bbrnetwork.com/downloads.
You will also find previous issues of CONNÆCT online as well as CAD files, specialist certificates, and contact details for Network Members around the world.



The BBR HiAm CONA stay cable system as featured in the brand new CONA brochure.

The BBR Downloads page features a wealth of resources to support sales, design and construction alike.

BBR HQ TEAM TRADES EXPERTISE IN MOROCCO

Our African BBR Network Member, Becomar, is making waves for its projects including the sizable Al Jabr International School in Tanger (page 58 of this issue) constructed in an incredible four-month window. With other, major infrastructure projects on the horizon, BBR senior management visited the team's contractors, engineers, designers and developers in Rabat, Morocco this November.
There, they learned more about BBR's geotechnical portfolio, with an overview of the ground anchor system and the full portfolio of GT Bars. These products will create further opportunities in other markets across Africa, where the team's post-tensioning expertise and use of BBR PT to reduce embodied carbon by using less material and leveraging the value of assets will be valuable. Becomar also offers design services.

The Becomar team enjoyed a presentation by BBR VT International's CEO Olivier Forget about the full range of PT technology available.

BBR NETWORK MEMBERS REPRESENTED IN SINGAPORE, TURKEY AND FRANCE

On 8th September, BBR VT's newest board member, Gianni Moor, who is also an Executive Member of Tectus, gave a talk at **BEX Asia 2023**, Singapore. He discussed how modern methods of construction (MMC), including those in Tectus's portfolio, could help bring down embodied carbon in a sector responsible for 40% of emissions every year. BBR Network had a presence throughout the show, running 6-8 September, appearing alongside Screening Eagle Technologies, Moderna Homes, and parent company, Tectus.

Gianni Moor (left), BBR VT board member, and colleagues on the Tectus stand, BEX Asia 2023.

From 5-7 June, BBR and Kappa our Turkish Network Member represented at the ***fib* Symposium** (International Federation for Structural Concrete/Fédération internationale du béton), Istanbul. According to BBR Network's Daniel Cuerdo, the event was busy: "We had a steady flow of visitors to the booth and spent quality time introducing our technology to newcomers."

The BBR Network welcomes visitors to *fib* Symposium, Istanbul, alongside Mehmet Yağız Ardal and Efe Bayram of Kappa, Turkey.

Conference Notes
BBR Annual Global Conference, Kuala Lumpur, Malaysia 2023

Convening in Kuala Lumpur

In May 2023, delegates from across the BBR Network traveled to Malaysia's capital, Kuala Lumpur, for the BBR Annual Global Conference.

The event is an unmissable occasion in the BBR calendar. Antonio Caballero kicked off the activities, giving a welcome speech to delegates during drinks in Bar Trigona at the Four Seasons Hotel Kuala Lumpur, the venue for the conference. This was followed by a tour of Petronas Towers, a major historical landmark.

Organizers weaved the technical/business program in with a fun and enriching cultural program. As part of the technical program, delegates enjoyed a series of presentations and case studies of BBR Network Member projects that showcased new ideas, approaches and technologies. An update on research and development advances by BBR VT International was especially eye-opening. As usual, the conference provided everyone with invaluable opportunities for learning and networking alongside socializing.

On the cultural side, activities included a visit to the Royal Selangor pewter factory and the Thean Hou Temple. Every opportunity to sample traditional Malay cuisine was seized. A particularly memorable moment involved eating traditional food at Tamarind Springs in the jungle. The BBR Gala Dinner and awards ceremony was a great ending to the event, before delegates enjoyed cocktails at Blue at EQ on the 51st floor, with stunning views over the city.

DRINKS BEFORE DINNER
Before the Gala dinner, delegates enjoyed drinks and conversation in the foyer (L to R): Dawn Neo and Dickson Liew from BBR CS Singapore.

AT DINNER
Delegates sampling traditional local cuisine during dinner at Tamarind Springs in the jungle, a unique setting.

Getting busy at Kuala Lumpur's Royal Selangor pewter factory. Royal Selangor is known globally for the quality of its pewter and the name is synonymous with craftsmanship. Here delegates are hammering letters onto the pewter before shaping the metal into a bowl.

Delegates enjoyed a visit to the Thean Hou Temple in Kuala Lumpur. The six-tiered, ornate temple, which opened in 1987, is an architectural marvel in the city.

SAYING A FEW WORDS
Paul Wymer giving a speech after receiving the Lifetime Achievement Award from Antonio Caballero.

CLOSING CELEBRATIONS
Delegates gathered on the 51st floor of the hotel at Blue at EQ, a bar that provided stunning views over the city of Kuala Lumpur. (L to R): Haifeng Fan (BBR VT), Gianni Moor (Tectus), Hemera Beretta (Tectus), Bruno Valsangiacomo (Chairman), Pawel Surman (BBR Polska) and Anna Surman.

BBR Awards 2023 Outstanding achievements by BBR Network Members

Awards for **Excellence**

BBR Network Members strive for excellence on every project they are involved in. The annual BBR Awards recognize and celebrate this excellence.

BBR Network Members are successfully delivering some of the most demanding engineering projects in the world – and every year, it only seems to become harder to pick a winner. In a crowded and competitive field, BBR Polska emerged victorious as winner of the BBR Network Project of the Year. The team, working on the Kamienna Góra-Lubawka section of the S3 Expressway, developed a solution to complete 10 flyovers and other structures for this 15.3km dual carriageway road section that will link Scandinavia and Greece.

More about
BBR Project of the Year

2023 BBR Award Winners

BBR Network Project of the Year Award

Congratulations to BBR Polska for the S3 Expressway in Poland. This project won for its success in blending engineering, customer service, professionalism and creativity.

BBR CONNÆCT Best Article Award

Winner: ÆVIA
Title: Fit for the future, Viaduc de Bonpas, Vaucluse, France (p70)

Highly Commended: BBR Polska
Title: Stay cable challenge University Bridge, Bydgoszcz, Poland (p44)

BBR CONNÆCT Best Photography Award

Winner: BBR Siam
Title: Thailand's widest bridge RAMA III Bridge, Bangkok, Thailand (p65)

Runner-up: Contech
Title: Waitakere Dam, New Zealand Testing of dam anchors (p60)

BBR Network Project of the Year Award 2023

Former CEO of BBR VT, Juan Maier, giving the certificate of BBR Project of the Year 2023 to Pawel Surman from BBR Polska.

BBR CONNÆCT Best Article Award

Daniel Cuerdo from BBR VT (left) giving the certificate of Best Article Award to ÆVIA's Antoine Dupre (middle) and Pierre Lhote (right).

BBR CONNÆCT Best Photography Award

Marco Zucconi from BBR VT (second from left) giving the certificate for Best Photography Award to John Mo (left), YL Voon (second from right) and Jackie Voon (right).

Evolving our solutions with AQUILA

BBR has a history of collaboration, both within the Tectus Group family of companies, as well as external partners. After all, challenges shared are challenges halved. Teamwork has always been a major factor behind our shared success, as The Pioneers on pages 12-17 highlights. So, with the strategic drivers of expanding our solution set to sustain and grow competitive advantage and the macro trends linking asset value to sustainability, it makes complete sense to partner with AQUILA. The CEO of this relatively new member of the Tectus Group family, and BBR Board member, Gianni Moor showcases how AQUILA empowers our clients' asset management and offers Network Members an exciting growth opportunity.

BBR Board member, AQUILA CEO and Member of the Tectus Executive Committee Gianni Moor (left) in the field demonstrating AQUILA's capabilities.

Empowering asset management with data

AQUILA is a global technology and professional services company that provides a comprehensive structural inspection and software solution for built asset owners, designed to optimize asset management and streamline decision making processes.

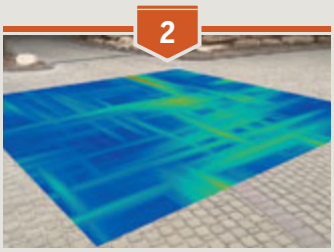
The inspection data is digitized and presented to the asset owner showing the building's health status. The digital health records enable the asset owner to extend asset lives, maximize productivity, increase asset values, and reduce carbon by taking informed decisions about the MRR of the built asset.

There are multiple benefits for BBR Network Member's asset owning and operating clients, which include:

- Creating and maintaining a continuous building health record that shows the current status of the asset
- Increasing asset values through extending building operating lives by identifying and fixing defects early
- Minimizing operational disruption and loss of revenue through predictive and planned maintenance rather than unplanned failures
- Enhancing safety and increasing compliance by identifying and fixing defects before they become disasters

By inspecting, perfecting and protecting a built asset, its value is enhanced, ongoing insurance and financing costs are reduced and its carbon footprint is lowered.

Inspect and digitize
Surveying the asset with leading-edge technology, digitizing data into health records.



Visualize and report
Digital data record reveals underlying structures and health status.

Monitor, predict and fix
Building health record data drives predictive maintenance and MRR.

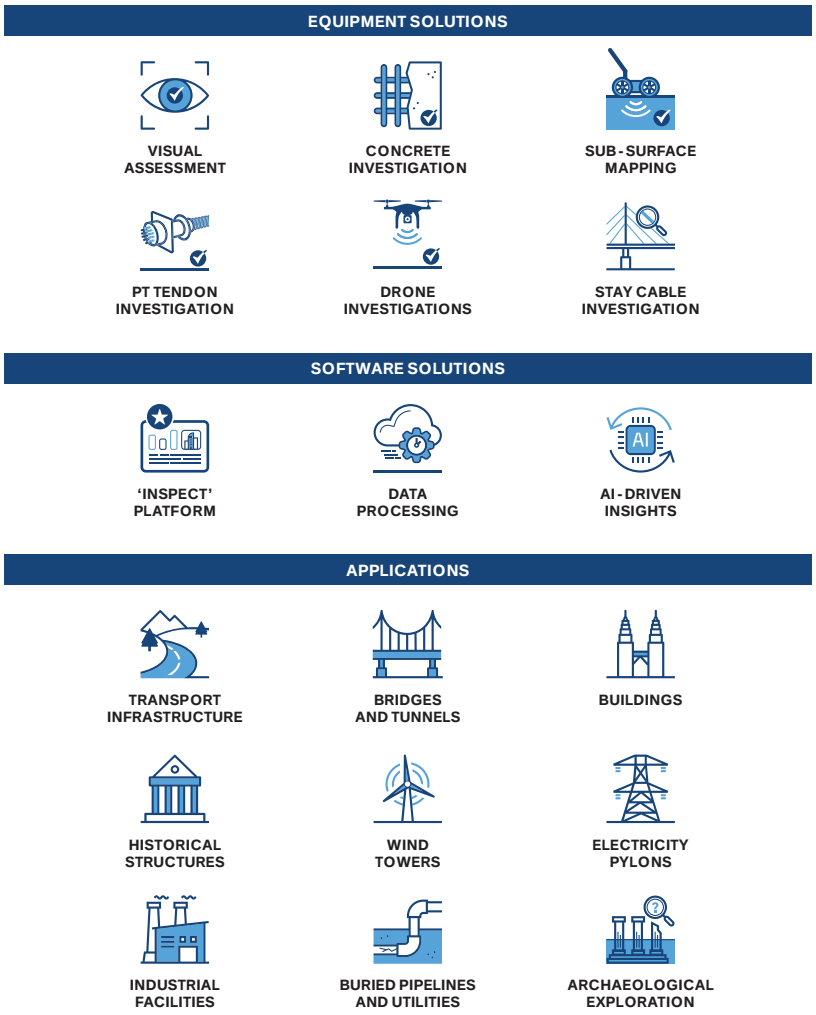
BBR Network Members benefit from recurring revenues by integrating inspection and MRR

We have BBR Network Members who are already experiencing the benefits of an AQUILA franchise, which provides an ongoing fee-generating relationship with clients, through direct revenue from inspection solutions and MRR services. This transforms business models from project-based to recurring annual software, inspection, monitoring and maintenance revenues.

Network Members will receive:

- Inspection engineer training, certification, and continued professional development
- Accessibility to the constantly growing knowledge database of use cases
- Availability of leading-edge inspection technology, analysis, and reporting software
- Knowledge sharing with the core AQUILA team and other AQUILA Network members
- Marketing and sales support, and global client opportunities within the AQUILA community
- Participation at global annual conferences as well as quarterly webinars

This article is a short summary of AQUILA's solutions and how it can benefit BBR Network Members and your clients, enabling you to seize the opportunities highlighted in Bruno's introduction and Olivier's Business Review. There is more information available at aquilainspection.com, where you will also find contact details for the AQUILA team.

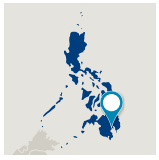


An AQUILA franchise comes with a range of cutting-edge equipment and software solutions, plus the training and technical support required. The AQUILA team's expertise includes all main built asset classes.

Evolving our Network to be successful together

During April 2024, we welcomed two new BBR Network Members: Phoenix Specialist Contracting Ltd. in the UK and Ireland, and De Vries Vsp b.v. in the Netherlands and Belgium (New Member Profiles can be found on pages 92 and 93). In his Business Review (pages 18-21), our CEO Olivier Forget highlights the importance of Network growth for all Network Members. "We have a global strategy to grow our presence," highlights Olivier, and this has started with the key European markets of the UK, Ireland, the Netherlands and Belgium. The ambition to grow is shared, says De Vries Vsp's Jan Luijten: "We want to grow our geographical coverage wherever possible." Phoenix SC Director Alistair MacQuarrie adds: "The BBR Network seemed the perfect fit to develop our technical presence and credibility."

By expanding our Network, we all benefit and grow our businesses. BBV VT International CEO Olivier Forget welcomes De Vries Vsp Director Jan Luijten to the BBR Network.



BBR Philippines Corporation
Talomo-Matina Bridge, Davao City, Philippines
BBR VT CONA CMI and BBR VT CONA CMF for incrementally launched bridge

First incrementally launched bridge in The Philippines

In a fast-expanding city plagued by traffic congestion, the Talomo-Matina bridge in Davao City had a lot of problems to solve.

The country's Department of Public Works and Highways (DPWH) chose AAAA Company Contractor Ulticon Builders to construct the 660m Talomo-Matina bridge. This bridge, part of the DPWH's Davao City Coastal Bypass Road project, was designed as an alternative route into Davao City, the third major city in The Philippines and a growing urban area that must expand and strengthen its infrastructure to solve issues with traffic congestion.

The original plans for the bridge called for a cast-in-place, four-cell box girder superstructure. This posed a problem for the main contractor, Ulticon Builders, as the construction scheme would have made it difficult to meet the completion deadline requested by the The Philippines government. In February 2020, Ulticon Builders asked BBR Philippines to devise a superstructure construction scheme solution that would save on time and cost.

BBR Philippines enabled Ulticon Builders to achieve optimal design efficiency with the bridge superstructure while reducing the structural quantities of reinforcing steel bars, concrete and post-tensioning.

The bridge superstructure's design

The bridge superstructure has a total width of 19.62m, inclusive of sidewalks. The plan was for it to accommodate two lanes of motor traffic in both directions. The bridge is straight with a vertical curved radius of 43.6965m x103 and the elevation of the abutment and pier substructures is equal. These configurations made it easy to choose an incremental launching method (ILM) to construct the bridge superstructure.

BBR Philippines had no experience with the ILM, so contacted the regional office in Singapore who re-engaged Swiss firm Meichtry+Widmer (M+W) for the design. The designers recommended a single cell box girder with a constant height of 3.29m and a bottom width of 9m. The design simplified the formwork system needed to fabricate the precast segments compared to the original four cell box girders. This made it possible to reduce production cycle times. In total, 34 precast segments were detailed for the entire length of the bridge.

However, there was a drawback to the proposed design. A steel launching nose would need to be designed and fabricated overseas, transported to Davao City and assembled before the ILM Construction could start. Together with the construction of the precast yard behind one of the abutments, it would likely be six months before the ILM could be used.

As the bridge substructures were already completed, Ulticon Builders could start with the cast-in-place construction at any time.

1

The COVID-19 pandemic causes delays

Lockdowns delayed the start of the project, but also provided a window to prepare the casting yard and the supply of the launching nose.

Ulticon Builders awarded BBR Philippines the ILM superstructure construction project in April 2021. By June of that year, work began on the fabrication of the 200t steel launching nose. BBR Philippines chose a steel fabricator in Johor Bahru, Malaysia, to carry out the fabrication as they have a close partnership with BBR Singapore and BBR Malaysia, and their supervisors could inspect the works. At that time, Filipino nationals were not allowed to travel overseas except in specified emergencies. Virtual meetings allowed us to still co-ordinate effectively.

BBR Philippines sourced the system formworks, stressing jacks and hydraulic pulling system for the incremental launching from Singapore through guidance from BBR Singapore. The aim was for everything to be at the project site for November 2021. This was achieved, but ILM construction was delayed further due to government regulations preventing foreign nationals from traveling to the Philippines without a travel permit. As a result, the BBR expatriate team was only able to enter the country from late January 2022.

International travel restrictions were relaxed in February and the designers visited the site in early March with BBR Singapore's managing director. The first precast segment was cast later that month. The box girder segments were fabricated in two concrete pours, with the bottom slab and the webs cast first, followed by the upper slab. High strength concrete allowed the team to stress the post-tensioning tendons just one day after casting the box girder's upper slab.

2

3

Smoothing the path to project success

The sliding bearing pads caused problems and hindered progress with the pushing of the precast segments. Sliding pads with improved detailing were needed to allow the quick launching of the precast segments, and these had to be delivered from China.

From the estimated ten-day cycle time, it was assumed the incremental launching works would be completed within 12 months. The team was able to achieve a 6-day cycle time on multiple occasions and the last precast segment was launched into place in January 2023, almost two months ahead of schedule. The launching nose was dismantled and the post-tensioning of the continuity tendons were completed in March 2023, and the bridge formally opened to traffic by the country's president on 1 July 2023.

Against the backdrop of the COVID-19 pandemic and restrictions on travel, this project was a highly successful collaboration between engineers located around the globe. Mabuhay!

BBR technologies on this project:

- Longitudinal post-tensioning tendons were 1206, 1906 and 3106 BBR VT CONA CMI tendons
- Longest longitudinal tendons were 130m
- 16 transverse post-tensioning tendons were introduced at the first and last precast segments using 406 BBR VT CONA CMF tendons spaced equally at 850mm at the upper slab
- Length of the transverse tendons was constant at 19.62m
- Total post-tensioning tonnage for the single cell box girder bridge superstructure 683t.

1 Completed in 2023, the Talomo-Matina Bridge is a core element of the Davao City coastal road, opening many economic opportunities, and generating huge journey time savings for the city's residents and visitors.
2 The tendon ducts laid before the next bridge section is cast.
3 As well as coordinating the design, BBR Philippines installed the PT system of BBR VT CONA CMI tendons for longitudinal tensioning and BBR VT CONA CMF tendons for the transverse tensioning of the bridge segments.

TEAM & TECHNOLOGY

Owner/developer – Department of Public Works and Highways, Republic of the Philippines (DPWH)

Designer/architect – United Technologies Consolidated Partnership

Main contractor – Ulticon Builders, Inc. (UBI)

Superstructure contractor/PT design – BBR Philippines Corporation/Meichtry+Widmer (M+W)

Technology – BBR VT CONA CMI and BBR VT CONA CMF

BBR Network Member – BBR Philippines Corporation (BBR PC)

1

BBR Adria d.o.o.
The Balkans
BBR VT CONA CMI for transport infrastructure

Heights of achievement

Two of the most breathtaking transport infrastructure projects under construction anywhere rely on BBR Adria's post-tensioning work: a road bridge in Bosnia and Herzegovina and a railway viaduct in Slovenia.

When you are traveling 100m above the ground, it is comforting to know that the structure supporting you is reinforced with BBR VT CONA CMI's 1906 electrically insulated pre-stressing cables (EICs). BBR Adria was responsible for the post-tensioning work on a towering new bridge and 55m-high viaduct.

2

1 Počitelj bridge, Bosnia and Herzegovina
Nearing completion, the 100m-high, 945m-long Počitelj bridge will be the largest in Bosnia and Herzegovina. The structure, named after a historic settlement nearby, crosses the M-17 road, the Neretva River and the Sarajevo-Ploče railway line.
It forms an important part of Corridor Vc (CVc), a pan-European transport project that connects the Adriatic Port of Ploče in Croatia with the Hungarian capital, Budapest.
The section in Bosnia and Herzegovina, some 325km long, will cross the country from north to south. It is Bosnia and Herzegovina's first major motorway and largest infrastructure project to date.
The bridge is a continuous pre-stressed girder bridge with a main span of 147m. It features a variable cross-section and a free cantilever construction method for the span construction. It takes 38,000m^3 of concrete and 9,000t of reinforcement, plus 20,000m^2 of asphalt and waterproofing.
To pre-stress the bridge, BBR Adria has employed 1,500t of BBR VT CONA CMI's 1906 electrically isolated prestressing cables, housed in ribbed plastic ducts with channels for grout injection. 20,000 remain to be installed in the coming period.
The ribbed design of the plastic housing facilitates a stronger bond between the cables and the concrete, further enhancing the structure's resilience against tensile forces. Injection channels allow for the efficient filling of voids with grout, ensuring that the cables are completely encapsulated and protected from environmental factors.
Funded by a loan from the European Investment Bank (EIB) and through the Western Balkans Investment Framework (WBIF), the bridge is expected to open to traffic in 2024.

3

2 The Vinjan railway viaduct, Slovenia

This stunning structure forms part of a 27km-long replacement of the Divača-Koper railway line in Slovenia. The project, 20 years in the planning, cuts 17km off the existing route and reduces travel times by about a third. The new line, supporting speeds of 160km per hour, will provide an efficient railway link between the cargo Port of Koper and Slovenia's existing rail network and, consequently, the wider European rail network. It runs over two bridges, two other viaducts, and eight separate tunnels – for 75% of the route, the last two tunnels are connected by this viaduct.

Constructed using the balanced cantilever method, the Vinjan viaduct comprises main spans of 100m each. The viaduct's seven-span design includes a box-like cross section 8.5m wide, with a variable height ranging from 4m to 6.5m, ensuring structural integrity and durability.

The viaduct's tallest column, standing at an impressive height of 55m, features a streamlined cross section for aerodynamic efficiency. It is seamlessly integrated into the span construction through monolithic attachment, enhancing the stability.

BBR Adria's work on the viaduct included post-tensioning with BBR VT CONA CMI's 1906 electrically isolated cables (EICs), housed in ribbed plastic ducts with channels for injection. Isolating and insulating the tendons with specialist grout and sealed with anchor heads and protective caps protects against corrosion, extending the lifespan of the viaduct.

1 The Počitelj bridge soars 100m above the stunning landscape of Bosnia and Herzegovina.
2 Using the free cantilever method for the Počitelj bridge construction means building out the bridge modules from the pier, casting each module in place and stressing the tendons before the formwork is moved for the next segment. The mobile formwork can be at each end of the bridge segment, with the tendons to post-tension the bridge deck showing.
3 The Vinjan viaduct beautifully illustrates the balanced cantilever method of construction, building out the segments from the pier, and stressing before the formwork is moved and next segment is cast.
4 The finely balanced bridge segments will meet to complete this span. The cable duct can be seen on the right-hand concrete module's face, which will be filled with specialist grout to electrically isolate the cables and protect against corrosion.

4

TEAM & TECHNOLOGY

1 POČITELJ BRIDGE

Owner/developer – Autoceste Federacije BiH
Designer/architect – IRD Engineering
Main contractor – Azvirt Limited Liability Company (Azerbaijan), Sinohydro Corporation Limited (China) and Powerchina Roadbridge Group Co. Ltd. (China), Hering d.d. (Bosnia & Hezegovina)
Superstructure contractor/PT design – IRD Engineering
Technology – BBR VT CONA CMI EIT
BBR Network Member – BBR Adria

2 THE VINJAN RAILWAY VIADUCT

Owner/developer – Ministry of Infrastructure, Slovenian Infrastructure Agency
Designer/architect – PIPENBAHER INŽENIRJI d.o.o., Ponting inženirski biro d.o.o.
Main contractor – Kolektor CPG
Superstructure contractor/PT design – PIPENBAHER INŽENIRJI d.o.o., Ponting inženirski biro d.o.o.
Technology – BBR VT CONA CMI EIT
BBR Network Member – BBR Adria

BBR Polska Sp. z o.o.
Poland
Multiple technologies for road infrastructure

From pole to pole by road: BBR Polska connects the country

BBR Polska is playing an outsize part in Poland's National Road Construction Program, which aims to build around 8,000km of road by 2033 at a cost of PLN 290 billion ($73 billion).

1

BBR Polska is contributing to the expansion of its country's roadmap, which has grown more than 40% over the past five years and includes more than 2,500 new bridges. CONNÆCT speaks to three engineers behind three standout schemes to discuss their use of BBR technology, with a spotlight on the BBR VT CONA CMI Movable Coupler.

1 National road DK47 bridges, Michał Chrostek

According To Michał, since 2021, BBR Polska has been involved in constructing a 16km section of national road 47 (DK47) that links Kraków, Poland's cultural heart, with Nowy Targ, gateway to the famed mountain resort of Zakopane. This section of road is notorious for severe traffic jams, particularly during the peak holiday season.

As the section connects to a ski resort in the Tatra Mountains, road building required bridge construction. BBR Polska was responsible for 17 of these, ranging from single-span bridges to complex multi-span bridges. A range of building techniques were used, including stationary scaffolding, incremental launching and cantilever methods.

The longest bridge in the project is almost 700m long with 24 incrementally launched segments for each of its two separate lanes.

BBR Polska supplied the post-tensioning (PT) materials and conducted PT works on pre-stressed bridges. The team installed over 2,500t of seven wire PT steel strands along with hundreds of tendons in different configurations, ranging from 12-strand to 31-strand. These were tensioned to more than 2,500 BBR VT CONA CMI and CME anchorages, mounted, stressed and grouted as internal and external PT tendons in compliance with BBR's ETA-06/0147 and ETA-07/0168, and Eurocode standards.

The most intense phase was between spring and late autumn 2022. It demanded meticulous resource planning and team coordination. Multiple stressing, strand installation and grouting operations took place simultaneously in different locations over a large site. This was achieved with limited resources, workers and equipment while maintaining morale and the PT material supply chain. The final bridge was completed in spring 2024. ›

2

1 Incremental launching method, with the BBR VT CONA CMI tendons showing at the end of the bridge segment.
2 Constructing bridge MD119 using the cantilever method.

3

4

2 Expressway S11, Jacek Sowa

With a target completion date of 2030, the Expressway S11 is one of the most important road projects in Poland, explains Jacek. Its 550km length will link the country's north and south. His BBR Polska team is constructing the 11.6km-long Koszalin Południe to Bobolice section. This includes a 326m-long two-lane flyover crossing a valley between forested areas, ES-39.1.

ES-39.1 consists of six 42m spans with two 36m spans at either end divided into four construction phases of two spans each. They were stressed with 16, 24 and 25-strand internal tendons. The initial design was for 50% of the tendons to be stressed from one end and the remaining 50% extended to subsequent spans, but this required extra scaffolding.

In a first for BBR Polska, the team successfully proposed using a movable coupler to the main contractor – a standard BBR VT solution, used elsewhere for 15 years (see box). This solution enabled the scaffolding to be moved and reused.

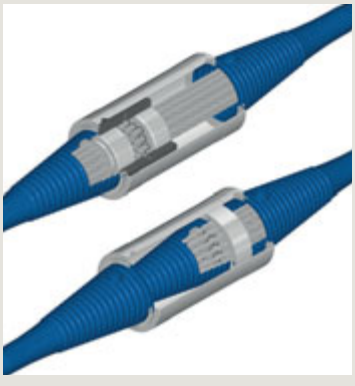
The team had to consider the elongation of the tendon, the clearance needed for the anchor inside the housing, the grouting procedure, the positioning of vents for grouting, and the connection of the housing.

Despite installing large steel tubes and strands among the reinforcement under extreme winter conditions, implementation on-site went exactly as anticipated.

BBR VT CONA CMI Movable Coupler

The BBR VT CONA CMI Movable Coupler creates tendon continuity, enhancing efficiency and reducing costs in PT. Their position along tendons can be adjusted to accommodate construction phases, manage tendon length and ensure effective tensioning across a structure, optimizing the post-tensioning process.

The tendon was extended beyond the already-cast part of the structure, allowing construction to begin without needing scaffolding for subsequent sections. Once the scaffolding was moved, a separate tendon was coupled from the opposite end, installed and tensioned. This is a cost-effective solution for managing post-tensioning complexities on large-scale projects.



Fixed and movable couplers are available for the BBR VT CONA CMI range.

5

6

3 BBR Polska installing a steel housing, part of the movable coupler.
4 The movable coupler obviated the need for extra scaffolding.
5 The SAG Tarnów bridge includes Poland's longest concrete beam span.
6 Balanced cantilever concreting technology was used on bridge M2.

3 SAG Tarnów bridge, Marek Strzoda

In CONNÆCT 2023, we learned about BBR Polska's involvement with Poland's longest span, 185m of the SAG Tarnów Bridge (p.33). This project enables cars to bypass the city on the Dunajec river (M2 on the plan).

M2 is a single-chamber box girder with cantilevers. Its structural design is a three-span continuous beam with a central length of 185m and two flanking 100m spans. The height of the load-bearing structure varies from 3.5m in mid-span and above flood span supports, and 8.5m above current span supports.

The crossing on Provincial Road 973 also required two access flyovers: M1, approximately 347m with seven spans, and PT work was needed on M3, a two-span 78m structure. While on-site between February 2022 and May 2023, BBR Polska used different construction techniques and technologies on the three elements.

The spans on M1 were constructed on stationary scaffolding, span by span. M2's spans employed balanced cantilever concreting technology, while spans for M3 were constructed on stationary scaffolding in a single phase.

BBR technology played a pivotal role in reinforcing the bridges, using pre-stressing cables such as BBR VT CONA CMI 1206 for M1; BBR VT CONA CMI 1906 for the upper and bottom cables of M2 and for M3, and BBR VT CONA CMI 2206 for M1.

The most significant challenge was the assembly and grouting of cables over 182m on M2's balanced cantilever structure. The logistical coordination of a single team of workers, the four-person 'assembly brigade' including two BBR technicians across three independently implemented bridge structures.

All projects were handed over in December 2023 to serve local residents.

TEAM & TECHNOLOGY

1 NATIONAL ROAD DK47 BRIDGES

Owner/developer – GDDKiA Oddział w Krakowie
Designer/architect – Autostrada II, INMOST-PROJEKT, MOSTEX
Main contractor – INTERCOR
Superstructure contractor – INTERCOR
Technology – BBR VT CONA CMI and CME
BBR Network Member – BBR Polska

2 EXPRESSWAY S11

Owner/developer – General Directorate for National Roads and Motorways (GDDKiA)
Designer/architect – Trakt/Mosty Gdańsk
Main contractor – KOBYLARNIA S.A., MIRBUD S.A.
Structural engineers – Lafrentz Polska
Technology – BBR VT CONA CMI
BBR Network Member – BBR Polska

3 SAG TARNÓW BRIDGE

Owner/developer – Zarząd Dróg Wojewódzkich w Krakowie
Designer/architect – M3M Sp. z o.o. sp. k. + Highway Sp z o.o
Main contractor – Metrostav Polska S.A.
Superstructure contractor – Makax Sp. z o.o.
Technology – BBR VT CONA CMI
BBR Network Member – BBR Polska

BBR Construction Systems Pte Ltd
Jurong region line, Singapore
BBR VT CONA CMI internal for light rail line construction

Tracking success in Singapore

By 2029, 600,000 more Singaporeans will be within 10 minutes' walk of a train station thanks to the completion of a new light railway, the Jurong Region Line (JRL). At the halfway point, BBR Construction Systems will help complete the transit system.

With construction on the JRL progressing towards scheduled phased opening between 2027 and 2029, BBR Network Member for Singapore BBR Construction Systems has doubled the amount of station packages secured from the two covered in CONNÆCT 2023 (p30) and increased the requirement for BBR VT CONA CMI BT internal technology.

A workload boost

Spanning over 24km, the JRL is predominantly an elevated light rail mass transit line comprising 24 stations, including three interchange stations that connect with existing MRT lines. It improves connectivity for important nearby destinations, such as Nanyang Technological University. The JRL's design emphasizes sustainability, with all stations equipped with solar panels and natural ventilation systems, and trains featuring energy-saving technologies.

The JRL navigates densely populated areas, requiring modifications to existing infrastructure and the use of advanced technologies for planning and real-time monitoring. There is the additional challenge of constructing tight curves along the viaduct, necessitating smaller train carriages to ensure maneuverability.

BBR Construction Systems has made progress on two contracts: J105 and J106. Pre-cast work for J105 Jurong West and Bahar Junction stations started in November 2022 and reached 45% completion by December 2023. It includes viaduct launching by segmental balanced cantilever method of precast segments, post-tensioned beams and crossheads.

Work started on the adjoining contract, J106 for Boon Lay Station, in July 2022. The viaduct launching is 40% complete and most of the pre-cast segment work is completed.

1

By December 2023, it was 70% completed. Launching for the packages will be finalized in October and June 2024, respectively.

The new contracts include the J111 package involving the design and construction of Enterprise station, Tukang MRT station, and associated viaducts. This package presents unique challenges, such as crossing parks and canals and navigating through industrial areas. Pre-cast work started in October 2023, physical site work on the crosshead in December 2023, and completion is set for April 2025.

Due to the various crossings, J111 will feature portal beams of up to 6m in depth to support the pre-cast segmental viaduct. Sections of the viaduct will be constructed in situ using the movable form traveler system to overcome difficulties in delivering large pre-cast segments.

The T235 contract (not shown) is part of the Rapid Transit System (RTS) link project. It involves constructing a viaduct and tunnels to connect Singapore with Malaysia. This requires careful sequencing to avoid disrupting shipping navigational channels, with some segments designed to accommodate large ships passing below the completed bridge. Completion is planned for November 2024.

When fully operational in 2029, 60,000 more households will be within a 10-minute walk of the JRL, which will half journey times for many commuters.

1 A section of the JRL bridge as seen from below, showing the precast concrete segments.
2 Precast segments are loaded into position.
3 Approximate location of the three station and viaduct contracts. Source: LTA
4 Cast segments awaiting the form traveler and showing the PT tendon ducts.

2

3

4

TEAM & TECHNOLOGY

Project – Jurong Region Line – Contract J111 & RTS – Contract T235
Owner/developer – Land Transport Authority
Structural Designer – Aecom Singapore
Main contractor – China Harbour (Singapore) Engineering Company Pte Ltd & China Communications Construction Company Ltd (Singapore Branch)
PT Specialist – BBR Construction Systems Pte Ltd
Technology – BBR VT CONA CMI BT internal
BBR Network Member – BBR CS Singapore

Canadian bbr Inc.
Oakville, Canada
BBR VT CONA CMI internal for bridge

Bridge building at winter's height

In Oakville, Canada, winter temperatures average between -3.3°C and -5.1°C. Building a new bridge during these months required some ingenuity if exposed tendons were to maintain their integrity. Canadian BBR had the solution.

The town's William Halton Parkway extension is important to its east-west route by reducing congestion on Highway 5 (Dundas Street). Bot Construction Group is running the CAD 80 million (USD 56 million) Halton Region bid-build contract responsible for building two new bridges that carry cars over a river. Additionally, a new 4km, four-lane extension and two roundabouts. Canadian BBR advised the bridge's designer, Danish consultancy COWI, and installed longitudinal and transverse tendons for post-tensioning.

1

2

1 A segment of the south bridge showing the anchor points.
2 Canadian BBR and Bot Construction work together to create bridge segments with the form traveler.
3 The bridge is being constructed across a breathtaking gorge.
4 Ducts in the William Halton Parkway deck segment before pouring.

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Balancing balanced and unbalanced

The 280m, three-span William Halton Parkway bridge, the south bridge, is asymmetrical and built out differently from the east and west piers. The west pier has been built with a planned, unique, unbalanced cantilever design for the deck due to site constraints.

In early 2022, construction from the south bridge's east pier began and was formed via the balanced cantilever method. Canadian BBR got involved early after receiving initial drawings from COWI. The two teams developed the drawings, focusing on the bridge deck and cable stay elements on the spans.

Movable feat

The east pier was completed in summer 2022. Bot Construction and Canadian BBR created 27 eastward segments using a cast-in-place form traveler. This is a movable scaffold that supports the formwork for casting concrete segments. Some vertical pre-stressing bars were used at the piers. Concrete segments are cast in place on the form traveler, one at a time, starting from the pier and extending outwards. As each segment is cast with ducts for the PT tendons, it is allowed to cure and gain strength before stressing and movement of the traveler.

Skill in the chill

Canadian BBR was responsible for certain aspects of the post-tensioning process, including installation of the materials, stressing and grouting. The design of the post-tensioning system involved calculations for forces, eccentricities (deviations from the CGS), elongations (lengthening of the tendons) and procedures for placing the tendons within the concrete structure. The specific size of BBR VT CONA CMI tendons were 406 and 1906, proprietary products distributed by Canadian BBR.

The flat top tendons are transverse, and the round ducts are longitudinal. Segment casting and stressing took place in winter, while grouting was postponed until ambient temperatures increased.

Canadian BBR makes the spiral ducting in-house from galvanized strip run through a Spiro duct machine. The flat duct is run through a set of wheels and compressed to order. Once the balanced cantilever sections were finished, attention shifted to the unbalanced west span. With the form traveler dismantled, the first cable stay will be installed in June 2024.

Bridge work will be finalized in 2024 and the William Halton Parkway extension will open in 2025.

Better climes will come

Grout cannot be applied below 5°C, so alternative solutions were needed. Unable to construct an envelope around the traveler for heating due to the pier's height, the team used a temporary corrosion inhibitor, MC1 309, blown into the ducts as a stopgap until conditions improved for grouting. Canadian BBR knows the importance of weather temperatures in construction planning and execution and did what it does best: adapt.

TEAM & TECHNOLOGY

Owner/developer – Regional Municipality of Halton
Designer/architect – COWI
Main contractor – Bot Construction Group
Superstructure contractor/PT design – COWI
Technology – BBR VT CONA CMI internal
BBR Network Member – Canadian BBR

BBR Construction Systems (M) Sdn Bhd
Kuching, Malaysia
BBR HiAm CONA stay cable system for bridge

A sculptural congestion solution in Malaysia

The new Sungai Bintangor Bridge is the riverfront icon for renovations in the city of Kuching, Malaysia. Its elegant cable suspension system employs the BBR HiAm CONA Pin Connector technology.

This crossing not only serves as a vital transportation link but is also an architectural marvel. Construction began in December 2019 with the removal of the old bridge. The elegant structure spans the Bintangor River, offering a four-lane passage and linking different parts of Kuching.

1

Supporting the tourist trade

The bridge stands at the heart of Kuching's tourism revival, playing a pivotal role in enhancing the appeal of the riverfront. Malaysia's government has embarked on an ambitious plan to create an LED-lit waterfall and river walks, and to promote watersporting activities along the cleaned-up Sarawak River and its tributaries.

Designing a useful icon

The design of the Sungai Bintangor Bridge integrates functionality with aesthetic appeal. It comprises three inclined reinforced concrete pylons, two thinner and one thicker, supporting a distinctive asymmetrical tower. From the intersection of these four elements hang 32 cables, between 36m and 44m long, to support the bridge deck, an eye-shaped roadway which swerves around the tripod-shaped pylon. Eight of the cables are attached to either side of the two curving sections of road.

As well as adding visual interest to the area, the bridge provides an alternative route for drivers, easing congestion in the city and carrying traffic over a pedestrianized riverbank.

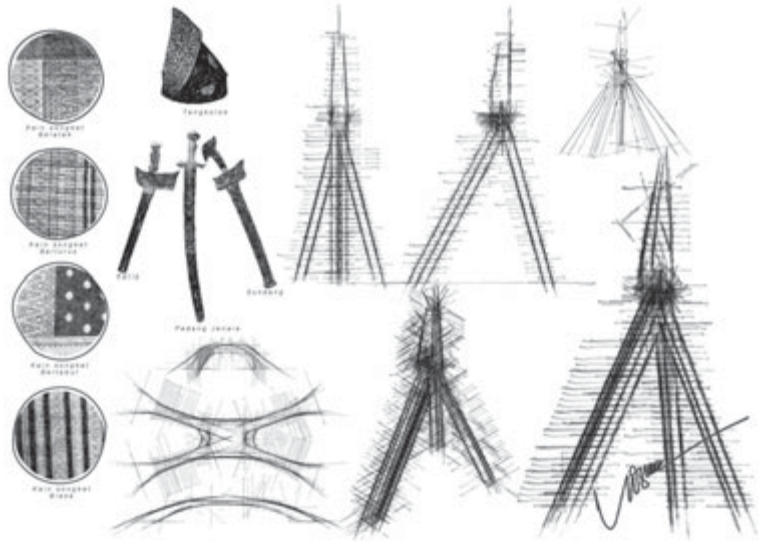
Flexibility built in

To accommodate pedestrians along the riverbank, the bridge's design required innovative engineering solutions; headroom restrictions meant the stay cable anchorages could not be located under the deck. Additionally, the client wanted the stay cable anchorages to be visible as part of the bridge's aesthetic, which include UHPC cladding around the bridge pylon and deck. The team used the BBR Pin Connector on the deck end of the cable.

The BBR Pin Connector is adjustable and gives cables 100mm adjustability by means of a turnbuckle and coupler. The cable is attached with a fixed pin to the pylon end. The deck-level pin connector adds to the positive aesthetic of the Sungai Bintangor Bridge, helped by the fact that it can employ slimmer cables.

Putting it together

Assembly began with the construction of the pylon top and deck. Following this, the stay cables, fitted with pin connectors, will be hoisted into place. The final phase, scheduled for June/July 2024, will involve tensioning the cables in a specific sequence to ensure structural integrity and aesthetic symmetry.



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1 The elegant bridge structure's pylon top and deck are being constructed over a tributary, from where it will be transported out to the main channel of the Bintagor River for assembly.
2 Early concept work by the design engineers Jurutera TCS shows how the iconic shape has been developed. The stay cables will radiate from the top of the pylon to support the deck, shown in the sketch top right.
3 The pedestrian boulevard, seen in between the pylons, will run underneath the vehicle deck, with the top stay cable anchorages located at the pylon tops where the reinforcement and formwork is shown.

TEAM & TECHNOLOGY

Owner/developer – Jabatan Kerja Raya, Sarawak
Designer/engineer – Jurutera TCS Sdn. Bhd.
Main contractor – Global Eco BBR Joint Venture Sdn. Bhd.
Technology – BBR HiAm CONA stay cable system
BBR Network Member – BBR Construction Systems Malaysia

SRG Global
Brisbane, Australia
BBR HiAm CONA stay cables for pedestrian bridge

Supporting over 10,000 pedestrians each day

SRG Global completes stay cable and damper installation on Brisbane's Neville Bonner Bridge that 500 ticketed guests tested during the annual Brisbane Festival Riverfire, ahead of its opening in late 2024.

The Neville Bonner Bridge has reached completion and is ready for the impending opening in late 2024 as part of the Queens Wharf Development. Summer 2023 saw the installation of 18 stay cables, a process overseen by the BBR Network Member for Australia, SRG Global's Project Manager Sean Kelly.

Linking the cultural quarter of Brisbane's South Bank to the new Queen's Wharf residential, retail and hospitality complex, the Neville Bonner Bridge has been designed with sustainability and social connectivity as the core drivers. Some 10,000 pedestrians will use the bridge every day when it opens. Edition 16 of CONNÆCT (page 48) highlighted how the hybrid mast and arch design minimized the landing points in the river and structural elements required for the 320m span, significantly reducing materials usage.

By March 2023, all the deck modules were in place spanning the Brisbane River and the adjacent M3 expressway, landing on the pier at Queen's Wharf. SRG Global's team then removed the temporary stay cables used to support the deck and mast during construction. According to Sean, it was a conventional staged installation that ran smoothly, reconnecting the top of the mast with the arch with two main 48-strand stay cables 130m long, ten stay cables connecting the deck with the mast on the span north of the pier, and six stay cables from the arch to the deck on the span south of the pier.

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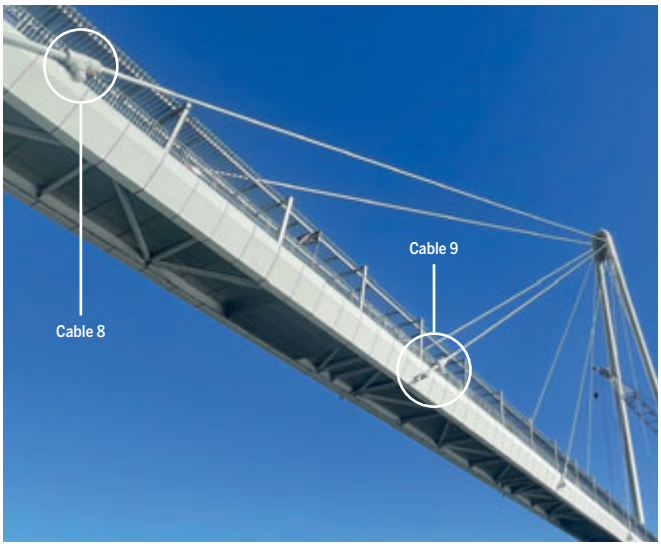

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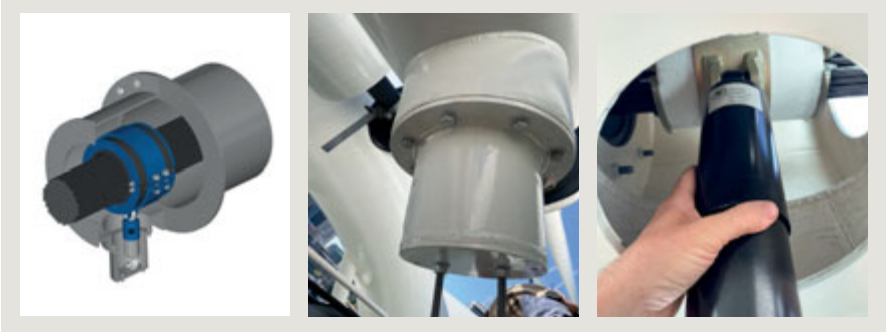
The temporary works and access control for the stay cable stressing team were designed and constructed by the lead contractor Fitzgerald Constructions. Uni head short sockets were used for the unstressed anchor heads in the arch and mast. This helped save on materials as they use less steel. As the construction stage and stressing analysis were accurate, the fine tuning of the cables was straightforward, with final adjustments performed with either the ring nut and multistrand stressing jack or via monostrand jacks if the extent of adjustment permitted. The process was completed with the final cap filling process with a flexible filler compound.

Overcoming wake galloping

Usually with cables over 100m in length, supplementary damping is needed to counter cable excitation under loading, and closely spaced parallel stay cables are prone to wake galloping. This is where, when subjected to dynamic loading such as from wind, the wake from one cable can place drag forces on its twin, causing oscillations that result in additional stress and even clashes between the cables.

Two mass tuned dampers were built into the deck to quiet resonant vibration. A separate analysis was completed on the stay cables based on the cable load, length, diameter and wind speed for the area. The damping solution was twofold: three cross ties stitched together the affected cable 4 at three points, and the BBR Viscous Damper installed at the anchorage. The viscous damper is essentially a hydraulic piston that dissipates energy, damping the cable's excitation.

Sean notes that the team's investment in preparation, from the calculations to the access control and finishing, led to a safe and conventional installation that was completed on time and to specification.



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1 Aerial view of the city of Brisbane, with Neville Bonner Bridge in the foreground.
2 BBR Viscous Dampers at the anchorage of stay cables 8 and 9 on the bridge deck to counteract vibrations on the stay cables in real-time by using resistance induced by viscous fluid passing through a narrow opening.
3 The completed bridge includes six BBR Viscous Dampers located on cable 9 upstream and downstream, cable 8 upstream and downstream and cable 4 upstream and downstream which is located at the top of the arch.
4 **Left:** BBR Viscous Damper showing the stay cable collar attached to a hydraulic piston. **Center:** A viscous damper attached to the stay cable during installation. The strands and strand collar can be seen above left of the damper housing. **Right:** The hydraulic piston that dampens unwanted oscillations, shown during installation.

TEAM & TECHNOLOGY

Owner/developer – Destination Brisbane Consortium
Designer/architect – Grimshaw Architects
Main contractor – Fitzgerald Constructions Australia Pty Ltd
Structural engineers – WSP
Technology – BBR HiAm CONA stay cables, BBR Viscous Dampers
BBR Network Member – SRG Global

Siam BBR Systems Co. Ltd
Bangkok, Thailand
BBR HiAm CONA stay and BBR HiBox Saddle for bridge

Civic ride: Bangkok's new road bridge

Thailand's rapid growth is placing pressure on the capital's transport infrastructure. BBR Siam installed specialized technology to prevent the decorative, non-pre-tensioned cable on Bangkok's new Kiak Kai Bridge from moving around.

Bangkok's new parliament complex has been generating significant extra traffic. Traffic volumes can reach 36,000 vehicles an hour, but existing bridges can only handle 30,000 vehicles. The solution is the Kiak Kai bridge, part of a larger planned 6km link that connects Thon Buri to Dusit District across the Chao Phraya River.

Cable vision

The three-lane, 350m-long bridge platform is suspended on 36 cables from two pylons, one larger than the other, both decorated with gold finials. The taller supports 24 stay cables and the smaller supports 12. Both have two decorative parabolic cables which are non-load bearing.

However, the wind can make these looser cables oscillate and 'gallop'. To prevent this, BBR Siam employed a BBR Viscous Damper with a fluid-filled chamber that converts movement into heat.

Where the draped cables need give, the stay cables must remain tensioned. Rather than the more usual anchorages, the team elected to use BBR HiBox Saddles to allow for reduced pylon dimensions (see box).

Piling began in October 2023, with the first cable tensioned in summer 2024 and a construction timeline of seven months from that point.

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1 The Chaopraya river cuts through Bangkok, an artery for those traveling by boat, but a barrier for the vehicle and foot traffic that's become the lifeblood of the city. BBR Siam's stay-cabled bridge will be the eleventh linking the Kai Kay district with Bangkok's new parliament complex.
2 The Kiak Kay Bridge complements Sappaya-Sapasathan, the New Parliament of Thailand where the National Assembly of the Kingdom of Thailand sits, with its iconic golden pagoda. The bridge also facilitates transport to the new government offices.

TEAM & TECHNOLOGY

Owner/developer – Bureau of Public Works, Bangkok
Designer/engineer – Span Company
Main contractor – NorCiv Engineering/Asian Engineering Consultants
Technology – BBR HiAm CONA
BBR Network Member – BBR Siam

Impressive saddles

The use of friction saddles installed in bridge pylons allows for a continuous and more efficient distribution of forces across the stay cables and without extra anchors. Traditionally, the tendons are passed through their multiple holes, centered, connected to deck-level anchors and pre-stressed. Despite the attraction of this method, saddles can suffer from fretting fatigue as well as slippage, and they are impossible to inspect or replace.

The BBR HiBox Saddle overcomes these drawbacks with a structural saddle embedded inside the concrete pylon and a stay cable section with anchorages directly seated on the extended part of it. Load transfer from the cables to the pylon is achieved via shear keys and a bearing interface between the bottom saddle surface and concrete pylon. The BBR HiBox Saddle lasts longer with less maintenance because its friction-free systems avoid fretting fatigue due to slippage.

The BBR HiBox Saddle prevents wear and tear on the cable by fixing them to the ends of the component.

SRG Global
Stockton, Australia
BBR HiAm CONA stay cable system for mixed-use bridge

SRG Global's platform for success

SRG Global allows crucial structural work to take place on the Stockton Bridge in New South Wales (NSW) through the design and maneuver of a work platform from the Hunter River to the underside of the crossing 30m above. Everything hung on BBR technology.

Kooragang Island is not a tourist trap, but its port, coal and other industries are important to the local economy. When Transport for NSW needed to make the bridge that links the island to the mainland fit for heavier traffic, SRG Global played an integral role.

Lofty goals

Built in 1971, the bridge's structural integrity was now compromised. SRG Global spearheaded the operation to engineer, design, manufacture, lift, fix, lower, relocate, lift, fix, then lower and dispose of a 23m x 11m work platform. The vertical lifting maneuver took four single-strand BBR tendons as part of a synchronized heavy lift strand-jacking system so that steel plates could be fixed to the bridge's exterior to increase traffic loading capacity.

In November 2022, SRG Global lifted the 27t platform onto a barge with a 130t crane. As it was too large to fit flat on the deck of the barge, an elevating stool was designed for it to sit on.

With the barge and platform heading towards the bridge, SRG Global drove a truck with the equipment secured on its tray. Once in position on the bridge deck, traffic disruption was minimized, and the shortest work stage could be achieved during night closures.

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The four, 70t strand lifting jacks were placed into position, powered up and attached to hydraulics. The strands were lowered and attached to the platform on the river through the small diameter holes which had been cored through the deck and soffit of the bridge.

The team used a BBR single-strand system with four, single-strand lift points configured with BBR mono-strand barrels and wedges for anchoring. The strand was secured into a bespoke transition anchorage at barge level using keeper grub screws.

To allow time in case of a sudden tide change, SRG Global designed a converter linking the strand and shackle for rapid attachment. Another mechanical system ensured no strand slippage since the load was relatively low. It took around five hours to set up, lift and lock off the platform.

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Fixed ideas

To lift and attach the platform to the multi-angled bridge, SRG Global created an adjustable base extension to the lifting equipment so the jack could be positioned vertically despite the bridge surface tilting in two directions.

Temporary parking beams were accurately located to transfer load into designated locations near the webs as the bottom slab was not structurally rated for the forces to be applied. The platform was connected to the bridge by a high-strength Macalloy post-tensioning threaded steel bar and secured laterally with separate bracing.

The works got off to a challenging start. A storm hurled 180km/h winds at the team just prior to the first lift, pausing the operation. Later, the platform was lifted into place and the load transferred to the temporary bracket, within the allocated single night shift.

The platform would be dismounted after the works before repeating the process. All four stages of the lifting and lowering had to be completed in a single night shift under partial traffic lane closures to allow through traffic.

1 Lifting the platform onto specially designed supporting stools on the barge.
2 Lifting the platform locked into position.
3 The strand jack on the bridge.
4 Mark Sinclair, General Manager, Engineering and Technical, operates the hydraulic system on the tray of the truck.

TEAM & TECHNOLOGY

Owner/developer – Transport for NSW
Main contractor – SRG Global
Technology – BBR VT CONA CMI strand for heavy lifting
BBR Network Member – SRG Global

Kappa Kalip Insaat Ve Taahhut A.S.
Nallihan, Turkey
BBR VT CMG PL2 for bridge foundation strengthening

Securing the foundations for growth

The Çayırhan bridge links two of Turkey's economic powerhouses: Eskişehir to the west and Ankara to the east. Challenging ground conditions with a nearby nature reserve meant that Kappa had to find a unique strengthening solution for the bridge's inclined piers' foundations.

Set for public opening in 2024, the Çayırhan bridge is Turkey's first cantilever bridge with inclined piers. The first part of the story was told in CONNÆCT 2023 on p32, with the original design influenced by the need to protect the nearby Nallıhan Bird Sanctuary. This need, alongside challenging ground conditions, makes it necessary to strengthen the foundations of the concrete abutment using BBR VT CONA CMG PL2 strand ground anchors with a 30m borehole depth. One key reason that BBR VT CONA CMG strand ground anchors were specified was the industry leading CE marked multiple level corrosion protection.

1

Boring detail shows PT's flexibility

The ground conditions are such that each abutment on opposite banks had 18 standard seven-strand 30m ground anchors to provide additional strengthening for the inclined pier's foundations.

Demanding site conditions led Kappa's engineers to request assistance from BBR VT's technical team in Switzerland, who quickly provided comprehensive support to move along the whole process. This included analyzing the site condition and base structure, refining technical solutions and providing detailed instructions for installing the ground anchors. The BBR VT team were also on hand to provide on-site assistance, working alongside Kappa's engineers during the installation of the first anchors in front of a delegation from the Directorate of Highways.

The BBR VT CONA CMG strand ground anchor's unique features had core advantages when overcoming the problematic ground conditions:

- Smaller borehole drilled in the concrete foundation, thanks to the proven DCP with single layer duct, which results in cost saving and time-efficiency
- The flexible and easy-to-install sealing device at the transition zone underneath the bearing plate, which allowed simple arrangement of the supporting structure, plus the sealing performance was maintained despite the large deviation and movement of the tendon during the installation process

Furthermore, the use of a drone for aerial photography of the site and recording the installation process, along with a mini-camera for real-time surveillance of the grouting level, clearly demonstrated the proficiency and innovative approach of Kappa's engineers. Together, the two teams of engineers worked through the challenges to deliver a successful outcome.

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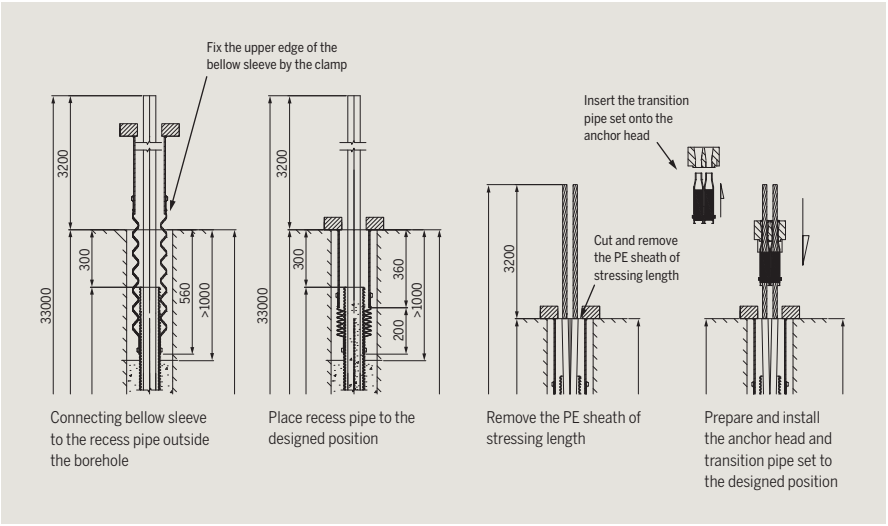

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1 The completed bridge will provide a vital link between two of the region's economic powerhouses.
2 Inserting a 30m strand ground anchor takes an expert team. Kappa's installation team receive training on BBR VT PT technologies annually.
3 The seven-strand 30m ground anchor has been inserted into the borehole.
4 The ground anchor's bellows provide flexibility, which ensures the integrity of the corrosion seal. The recess pipe is connected to the bellow sleeve with a clamp, outside of the borehole.
5 The recess pipe shown with a space between it and the design surface.
6 The transition pipe showing inside the anchor head.
7 A fast, flexible and elegant solution enabling the strand ground anchors to be installed with full certified corrosion protection.

TEAM & TECHNOLOGY

Owner/developer – 4th Regional Directorate of Highways, Ankara

Main contractor – Ankara Insaat Tic. Ve San. Ltd. Sti., Açılım Insaat Tic. Ve San. Ltd. Sti.

Technology – BBR VT CONA CMG PL2 strand ground anchors

BBR Network Member – Kappa (Turkey)

Stahlton AG
Zurich, Switzerland
BBR VT CONA CMI for highway infrastructure

Making the neighborhood whole

A long-planned project to enclose part of the busy A1 highway in Zurich and crown it with a new greenway was only made possible with crossbeams and other structural concrete pre-tensioned with BBR cables. BBR Network Member Stahlton AG carried out the installation to ensure its integrity.

Schwamendingen in Zurich, Switzerland, has long been a divided city district. Between 1980 and 2022, as many as 120,000 vehicles a day passed along the A1 motorway, causing noise and pollution and separating neighbor from neighbor. An emerging project has already sent traffic into a tunnel reinforced by Stahlton AG-installed BBR pre-stressing technology, and there's a tunnel-top park to come.

The green dream team

The Schwamendingen enclosure project has been decades in the making, a hard-fought collaboration between local people, Switzerland's Federal Roads Office and the canton and city of Zurich.

The enclosure and park creation represents just part of the work on this stretch of the A1, totaling 1.7km. The highway's Schöneich Tunnel, now connected to the enclosure's east end, was simultaneously remodeled. The ceiling was thus closed off, and exhaust air was extracted and expelled into higher atmospheric layers via a new exhaust chimney. This significantly improved air quality in the neighborhood.

Work also included remodeling of the Saatlenstrasse underpass through which neighbor can already visit neighbor by walking under the highway.

The complex project had to take account of continued traffic flow, a lack of space on-site, an underground tramway, and poor structural soil conditions. The length was divided into four sections and work scheduled in ten phases from 2018 to 2024, with multiple work items taking place concurrently at every length of the road. ›

An historic project decades in the making is set to improve the lives of Schwamendingen's residents.

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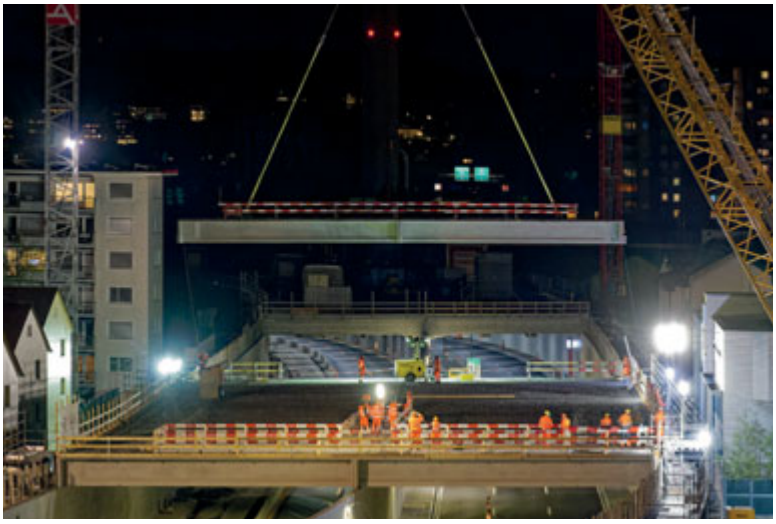

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A box in a tunnel

Designs for the enclosure show a greenery-topped 7m-high and 30m-wide box. However, due to site-specific factors, the team needed to build it as an open cut tunnel, wrapping the roadway for 940m between the road's Aubrugg highway junction and the Schöneich Tunnel.

The first of these factors was the Schwamendingen tram tunnel and station (serving lines seven and nine) which runs directly underneath the highway for 450m in the Schörli area. This could not be subjected to any additional loads. To protect it, the overhead roadway was strengthened with six, 70t pre-fabricated concrete crossbeams containing BBR VT CONA electrically isolated tendons (EIT).

The second issue was with the site conditions. The crossbeams are connected to walls as a support beam, strengthened with EITs. But the tendency of the subsoil to settle meant it needed to be supported on 1,250 piles driven 20m into the ground so the wall could support both the floor and roof of the tunnel – which would later support the park.

Keeping the peace

Constructing the complex enclosure in a limited area, and a support for the roadway larger than the existing space, proved additional site challenges. Some 19 buildings were partly or wholly demolished to accommodate works and storage before construction could start.

Building in the middle of a neighborhood of nearly 33,000 people demanded a strict noise reduction plan. The traffic needed to continue flowing and the Schöneich Tunnel was closed overnight during the installation of some elements while traffic was diverted.

Avoiding the trolley problem

The over-tramway section was one of the most complex parts of the build process. To divert the downward force of the enclosure on the 450m section above the tram, Stahlton AG tensioned six of the 234 concrete crossbeams with pre-stressing cables in two stages. The first work started in 2020 and the second in 2022.

2 Constructing the open cut tunnel early in the construction process. The suburb's residents were living very close to the construction site.
3 Constructing the roof of the enclosure over the A1 highway passing through Zurich's Schwamendingen, a project destined to finally link the populous suburb.
4 Supported by 20m piles, the post-tensioned tunnel walls support both the tunnel floor and roof.

TEAM & TECHNOLOGY

Client – Federal Office for Roads, Canton and City of Zurich
Architect – agps Architecture Ltd. Zurich
Engineer – Bänziger Partner AG, Zurich
Main contractor – ARGE EHS
PT design – Stahlton AG
Technology – BBR VT CONA CMI
BBR Network Member – Stahlton AG

The crossbeams all contain EIT from the European assessed BBR VT CONA system, internationally the most up-to-date and advanced multi-strand PT technology. Stahlton AG selected sizes 2206 and 3106, made up of between ten and 18 cables. The cables comprise more than 73,000kg of material.

All cables used in the Schörli area were coupled from the first to the second stage. This helped to mitigate the impact of friction on tension during stressing by creating a continuous and efficient load path for the applied forces.

The supporting wall was also designed to take EIT pre-stressing cables. The category C cables offer the maximum protection from the impact of water on the steel. Direct electrical contact between steel and surrounding concrete in the presence of an electrolyte can lead to accelerated corrosion. This 'galvanic corrosion' is reduced or eliminated by the EIT.

The pre-stressing cables are connected on both sides to a measuring cable, connected in sections to measuring boxes. This system provides real-time data on the performance of the roadway covering, assessing the effectiveness of the pre-stressing and the structural integrity of the system.

Structural support from end to end

The tramway was not the only part of the road enclosure that needed pre-stressing support. In 2022, the nearby Saatlenstrasse underpass was rebuilt as part of the project, requiring the use of more BBR VT CONA CMI EIT cables.

The section supporting the forest garden also took more pre-stressing technology although those were not EIT. Stahlton AG used the Dywidag WR 26.5 pre-stressed bar systems to introduce compressive forces into the concrete to account for the extra load of the trees and soil.

A green future for Schwamendingen

The most important part of the project, reducing the noise and pollution of the A1, was completed in 2022. Work to create the park and forest garden – Zurich's answer to New York City's High Line – was scheduled for September 2023. Once finished, it will be accessible via different entrances and connecting pathways, allowing Schwamendingen residents to meet over the motorway, this time in a green space. The green areas wrap around the side of the concrete body, partially covering it, taking away the hardness of the building and creating a dialogue between the new open space and the existing garden city.

From fumes to blooms

As far back as 1820, Schwamendingen was already an important location for transport – a village with 20 houses situated on the left bank of the Glatt river. Back then, more than 20 stagecoaches passed through daily. It became part of Zurich as District 12 in 1934 before hosting the four-lane A1 motorway, one of Switzerland's busiest routes, in 1982 as a feeder route to the A1.

As the Millenium approached, residents had had enough. They launched a popular initiative in March 1999, collecting 12,000 signatures to demand the partial covering of the motorway.

The initiative for enclosure prevailed after a comprehensive urban planning study in 2003, considering options such as a bridge and partial enclosure/partial lowering. In September 2006, Zurich's residents overwhelmingly supported the project, approving the loan proposal with 82.9% of the vote.

The green space on the enclosure is the project's most eye-catching feature for which Swiss landscape architecture firm Krebs und Herde tested plants for six years. The firm wanted to find out which species would survive on a thin layer of humus of 30-80cm and without irrigation.

Zurich city councilor Filippo Leutenegger, head of the civil engineering and waste disposal department, envisioned a 'prairie and savannah-like landscape.' After years of planning and political decisions, construction on the enclosure project began in 2019, supported by BBR Network Member Stahlton AG-installed BBR VT CONA pre-stressing technology. Completion is scheduled for 2024.

4

Stahlton AG
Zurich, Switzerland
BBR VT CONA CMI for exhibition hall

In it for the long hall

In 2022, Stahlton AG completed a road cover over the A1 motorway's Rosenberg Tunnel in St. Gallen, Switzerland, for the exhibition complex client, Olma Messen. Now the team would build their exhibition hall for 12,000 visitors over the top without it conflicting with the new construction.

The Olma Messen St. Gallen is the busiest conference center in eastern Switzerland, hosting trade fairs, congresses and cultural events.

1

Wanting to increase sales by a third from 30-40 million Swiss Francs over the next decade, the venue's owner needed to add extra capacity in the form of the new 9,000m² Olma Halle 1, recently named St.Galler Kantonalbank Hall. Stahlton AG constructed the post-tensioned cantilevered structural wall elements.

They've got it covered

The addition of the 150m by 90m St.Galler Kantonalbank Hall to the Olma Messen complex is just the latest Stahlton AG project in St. Gallen. Stahlton AG had previously installed a cover on 186,65t of pre-stressed beams, incorporating the BBR VT CONA CMI EIT over the A1 motorway's Rosenberg Tunnel. This was achieved with the help of a 1,300t crawler crane. The 180m-long roof forms part of the base of the column-free hall.

The road covering meant the structural loads of the large space could not be transferred to the subsoil. Instead, the engineers designed a system in which wide-span, cantilevered reinforced concrete box girders were placed on 12 5m-wide cores now known as the 'elephant feet'.

Work started in 2021. The anthracite-gray cores were sited 40m apart around the perimeter of the emerging hall space to support the walls. First, the team cantilevered the wall structure 5.2m left and right. The 'ring' was closed with Stahlton AG's pre-stressed hollow box system with double walls. These are up to 50m long and high – enough to allow space for an almost 14m interior.

Using double walls increased structural stability compared to a single wall and reduced the concrete thickness required. The wall cavities provided space for emergency stairs and service access. Once the box system was in place, the space between the supports was closed off at ground level with a wooden and glazed facade and roofed after Stahlton AG finished on-site in 2023.

Boxing clever

To create the hollow box system, Stahlton AG used reinforced concrete box girders pre-stressed with a post-tensioned slab construction method. Using the European-approved BBR VT CONA CMI system, the team specified 164 anchorage points attached to cables of between eight and 19 strands. After tension was applied, around 20t of cement was injected into the tendons. This combination of systems and strand counts allowed for flexibility in the design of the support grid for the hall and the concrete thickness to be minimized.

The partially completed St.Galler Hall was used for the first time as part of the 80th OLMA Swiss Exhibition for Agriculture and Food in October 2023, welcoming 330,000 visitors. Full completion was scheduled for March 2024 with seating for 7,500 people and space for 4,800 diners or 12,000 on foot.

Another project successfully executed by Stahlton AG.

2

1 Aerial view of Olma Halle construction site, April 2023, showing how the road and tramway go under the structure.
2 Building the structural walls on the construction site.
3 Post-tensioned roof showing distinctive blue PT caps, and the close proximity of the Olma Halle's neighbors.

Images courtesy of Michael Huwiler.

3

TEAM & TECHNOLOGY

Owner/developer – Olma Halle St. Gallen Cooperative
Designer/architect – Ilg Santer Architects
Main contractor – Stutz AG
Engineer – Meichtry & Widmer
Technology – BBR VT CONA CMI
BBR Network Member – Stahlton AG

Becomar
Tanger, Morocco
BBR VT CONA CMF and BBR VT CONA CMM for school

Carefully taut

Becomar led a masterclass in speed, efficiency and professionalism when the team installed BBR's post-tensioning technology at a new facility in a thriving international school in Morocco.

International school provision in Morocco is expanding. This expansion can be seen at the Al Jabr International School in Tanger. The language learning institution needed a new premises for its trilingual (Arabic, French and English) students, and so it turned to Becomar.

1

Playtime is over

The Al Jabr International School offers students a 'redesigned linguistic approach' to education. The school boasts excellent laboratories, a refectory and kitchen, and art and music classrooms.

For Becomar, the project involved the construction of three different buildings for teaching departments and administration spaces, with a total surface area of 9660.7m². The biggest challenge for the team was the tight schedule for completion. Works had to be finalized before the August semester following a March start. Time was in short supply.

Becomar provided the team, materials and plant and equipment to install the floor slabs in the structures using BBR VT CONA CMF and CMM. Post-tensioning with BBR technology was preferable to classic reinforcement due to the short construction timeline. BBR post-tensioning helped to reduce delivery times and increase the structural integrity of the large, wide spaces under long spans between the columns and walls. The team also managed to cut the number of materials used and, in turn, overall project costs.

The project's outcome was a success. Becomar surely gets a gold star for its role in helping to complete the construction of the new premises by June 2023 in an incredible four-month window.

1 Young students at Morocco's newest international school will learn in three languages.
2 Becomar and BBR's post-tensioning helped create wide spans and remove the need for obstructive columns.

2

TEAM & TECHNOLOGY

Owner/developer – El Ghali Lyoubi Idrissi
Designer/architect – Benhayoune Kacem
Main contractor – GIDNA
Structural engineers – Bureau d'etude technique ben yahia
Technology – BBR VT CONA CMF and CMM
BBR Network Member – Becomar

BBR Adria d.o.o.
Pula, Croatia
BBR VT CONA CMM for commercial property

Far-reaching business insight in Croatia

The Coworking Entrepreneurship Center in the Croatian city of Pula provides space for over 100 workers and features BBR post-tensioned ceiling slabs, panels and beams.

In recognizing the value of entrepreneurship to a country's growth, the European Regional Development Fund (ERDF) invested €2.4 million in the building, which opened in October 2023.

1

1 Preparing to pour the concrete slab on reinforcements. Ducts containing BBR VT CONA CMM unbonded cables.
2 Post-tensioned floor slabs enable the long spans between supporting pillars, opening-up the internal workspace.
3 The Coworking Entrepreneurship Center in Pula, Croatia, is post-tensioned with BBR VT CONA tech.

TEAM & TECHNOLOGY

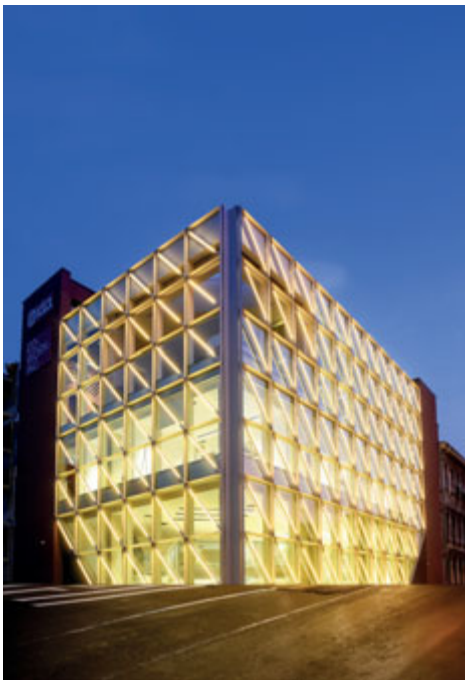
Owner/developer – Istrian Development Agency, Ministry of Regional Development, city of Pula
Designer/architect – Atelier Bruno Juricic
Main contractor – Lavčević d.d.
Superstructure contractor/PT design – C O I N, d.o.o., BBR Adria
Technology – BBR VT CONA CMM
BBR Network Member – BBR Adria

2

A center for enterprise and innovation for both the city and wider region, the building spans 1,500m^2. It is notable for its glass facade, enhanced with orthogonal and diagonal metal elements for pulsating night light effects.

Space to create

There are open spaces on the ground floor and mezzanine, dedicated offices for entrepreneurs on the second floor, and a large 120-seat hall with a terrace, 7m-high ceilings and a partial steel gallery on the third floor. The hall can be divided into two areas for concurrent events.
BBR Adria provided post-tensioning (PT) for up to 15m spans. This eliminated the need for columns or obtrusive reinforcement elements, such as beams or girders. Between November 2022 and March 2023, the team manufactured monolithic PT ceiling panels, created formwork and installed the reinforcement, cables, concreting and tensioning.
The PT slabs are designed as a combination of 22cm-thick PT plates supported by 200/60cm shallow beams. Internal BBR VT CONA CMM 0106 unbonded cables ensure structural integrity and flexibility.
So, when new ideas spark inside the co-working space, Croatia's entrepreneurs will have BBR Adria to thank.



3

Contech
Christchurch, New Zealand
BBR VT CONA CMF for warehouse buildings

Logistics, sorted

From small beginnings, Sorted Logistics has been making a name for itself since 2014, offering clients a full supply chain solution transporting goods and providing warehousing from purpose-built facilities developed along Waterloo Road in Christchurch.

Contech was called on to install post-tensioned slabs on a series of warehouse buildings on a multi-stage project, using BBR VT CONA CMF technology. As expected, the team met the challenge.

Stretching for almost 1,000m along a long, straight section of road and sporting Sorted Logistics' distinctive bright orange branding, the buildings are an eye-catching sight for anyone who drives by.

Four individual warehouses with adjoining yards have been constructed end to end as the company has grown. The first two stages were constructed in 2016 and 2017, while the fifth and final stage was completed in 2023.

1

Contech's role at each stage was to install in total 34,760m² of post-tensioned slab on grade across the four warehouse buildings. Individual floor areas ranged from 5,500m² up to 11,810m².

The first four stages, constructed between 2016 and 2019, were delivered by design and build construction company Apollo Projects. The warehouse slabs were delivered by flooring contractors Conslab during stages one and two of the project, and by Bartlett Concrete during stages three and four, using BBR VT CONA CMF 406.

The most recent and largest warehouse was completed in 2023 with direct engagement by the main contractor Calder Stewart, a long-time Contech client, using BBR VT CONA CMF S2 406. The slab thicknesses ranged from 165mm to 185mm to accommodate the required racking loads within each warehouse. Contech's involvement at each stage of the project proved successful.

2

1 Sorted Logistics' four warehouses run for a full kilometer along Christchurch's Waterloo Road.
2 BBR VT CONA CMF 406 flat anchorage post-tensioning system is used for ultra-thin concrete cross sections.

TEAM & TECHNOLOGY

Client – Sorted Logistics
Post-tensioning contractor – Contech
Main contractor (Stage 5) – Calder Stewart
Structural engineers – Engenium Ltd
Technology – BBR VT CONA CMF
BBR Network Member – Contech

Contech
Christchurch, New Zealand
BBR VT CONA CMI for building

From eyesore to elegance

Sometimes good things come from bad, and that's certainly been the case for an apartment building in Christchurch, New Zealand.

Left empty and uninhabitable after the magnitude 6.2 earthquake that devastated the city in 2011, the building has emerged triumphant as an architectural masterpiece. Contech was proud to be a part of its transformation, applying BBR VT CONA CMI technology to ensure a robust structure will stand for many generations to come.

1

A city landmark

Built in 2005, the Oxford Apartments were designed by well-known architecture firm Warren and Mahoney. Standing tall on the banks of Christchurch's Avon River, they were at the time one of the tallest and most distinctive buildings in the city. But just six years later, everything changed. At 12.51pm on 22 February 2011, the earthquake struck.

While many of the city's buildings were damaged beyond repair, the Oxford Apartments remained standing. However, their grip was tenuous. A post-earthquake design features report stated that 'developments in best practice since the time of the design have resulted in some original design and construction features now being considered as potential defects and deficiencies... the building's behavior, in response to the earthquakes, differed from that anticipated by the original design.'

The building was in a devastating state and was listed on the earthquake-prone buildings register as having a seismic rating of just 34% of the new building standard (NBS).

With its future bleak, it was named one of the central city's 'dirty 30' eyesores and written off by its insurers. It languished until 2018, when it was put up for sale on an 'as is where is' basis and bought by a developer for NZ$3.15 million. Two years later, it was sold again, this time to a proactive developer who pre-sold several apartments for several millions of dollars each. The building was saved and today offers a 'luxury collection of unique and exclusive residences' with 'unsurpassed craftsmanship and meticulously curated natural materials and finishes.' It is a pleasing result, especially as demolishing it would have released some 1,300t of carbon emissions into the atmosphere.

Separation is key

The main contractor, Dominion Constructors, separated out several packages of work as part of the upgrade to the building. Contech's role was to install vertical post-tensioning to increase the lateral capacity of the structure under earthquake loadings.

Other contractors jacked up the building and installed the damping bearings that would protect the structure from further earthquakes. Core holes were drilled vertically through the columns and eight BBR VT CONA CMI multi-strand post-tensioning tendons (four tendons x eight strands, two tendons x14 strands, one tendon x21 strands and one tendon x31 strands) installed over the full 37m height of the building from top to bottom.

Contech supplied and detailed top and bottom-end anchorage hardware. This was followed by tensioning using the 300t and 700t multi-strand stressing jacks. Once this was complete, the tendons were grouted, and caps were installed at the top anchorages for corrosion protection of the anchor heads.

A landmark once more

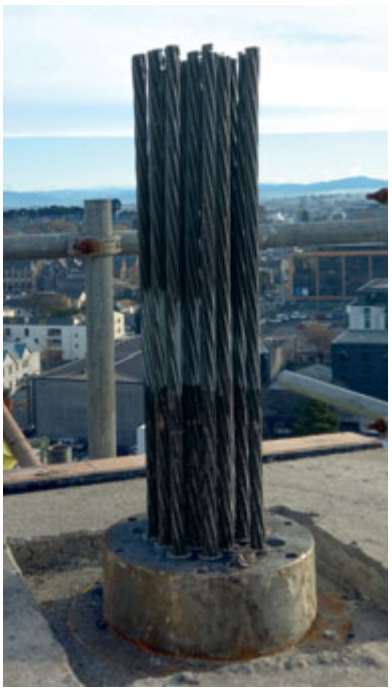
Today, it is satisfying to see the building once again standing strong on the city's landscape – an architectural icon that offers the best in inner-city apartment living. With its seismically stable foundations and Grade A+ seismic design, it will stay upright and safe for many years to come, neither earthquake prone nor an earthquake risk.

1 Elegantly refurnished Oxford Apartments standing tall on the banks of Christchurch's Avon River.
2 37m post-tensioning tendons installed at eight points increase the building structure's lateral capacity.
3 Multi-strand stressing jacks.
4 21-strand tendons awaiting stressing. Once completed, the tendons were grouted with top anchor caps for corrosion protection.

TEAM & TECHNOLOGY

Owner/developer – Russell Property Group
Architects – Warren and Mahoney Architects
Post-tensioning contractor – Contech
Main contractor – Dominion Constructors
Structural engineers – Structure Design/ Phoenix Consulting
Technology – BBR VT CONA CMI
BBR Network Member – Contech


2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4

BBR Saudi Arabia
Saudi Arabia
BBR VT CONA CMF for buildings

Redefining Saudi's urban landscape

BBR Saudi Arabia is extending the limits of what's possible in construction in Saudi Arabia.

BBR Saudi Arabia had already captured 60% of the region's post-tensioning market and expanded its workforce from 21 to 125 within five years of becoming a BBR Network Member (see CONNÆCT 2023, p34). Here, we cover four inspiring BBR Saudi Arabia projects that all feature the BBR VT CONA post-tensioning system. This technology was chosen for its efficient structural performance in large-span enclosures.

1

1 Jeddah Rose, Jeddah

This mixed-use building has two basement levels, a ground floor, and eight additional eight floors covering 35,600m². It also features a rooftop pool and spa, gym, restaurants, retail outlets, banquet halls and function rooms. Hard to miss is the viewing deck garden, which spirals at right angles from the 7th floor to the summit.

BBR Saudi Arabia delivered comprehensive PT design, supply and supervision services in an impressive 12-month timeframe. Post-tensioning helped to transfer beams, manage irregularities and accommodate inclined columns. The Jeddah Rose includes 150t of post-tensioning and 4,000 BBR VT CONA CMF S1 anchorages. The BBR VT CONA CMF multi-strand technology allows for post-tensioning in ultra-thin concrete cross-sections.

The design of the building's façade meant the team had to assess how much structural elements could deflect. The resulting structure is the embodiment of a successful collaboration between visionary design and precise execution.

2

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4

1 BBR technology is behind the unique shape and the creation of a spiraling roof garden in the Jeddah Rose. Reproduced with kind permission of PARALX.
2 PT technology allows the open, spacious internal spaces, such as the banqueting halls shown here. Using PT slabs during construction means faster build time with less materials. Reproduced with kind permission of PARALX.
3 The unique viewing deck gardens are a distinctive feature of the Jeddah Rose. Reproduced with kind permission of PARALX.
4 The National Border Museum is being developed to display the Northern Border Province's cultural heritage.
5 The cuboid structure weighs around 5,000t and is supported by PT slabs.

2 Northern Borders Museum, Arar

The Northern Border Museum at Arar was opened in 2007 to display the cultural and historical heritage of Saudi Arabia's Northern Borders Province. Now, an elaborate structure is being added: a pierced, sloping cuboid sunk into a raised platform.

This new space will reach around 40m at its highest point. The museum's development is an extreme engineering challenge, requiring the transfer of its 5,000t weight onto post-tensioned slabs.

The use of post-tensioning in walls and floors enables stiffening to resist lateral loads and the effects of gravity. The combined building engineering team must also account for temperature fluctuations resulting from irregularities, and stress concentrations at connections between the transfer slab and planted walls. Additionally, the building includes complex formwork. To address these challenges, BBR created a sophisticated solution using 4,000 BBR VT CONA CMF anchorages together weighing 150t. ›

5

6

6 A distinctive addition to Riyadh's skyline, The Stage Center has large span internal spaces, enabled by PT.
7 BBR Saudi Arabia's team laying the PT tendons.
8 Over 6,000 BBR VT CONA CMF anchorages are being incorporated into Riyadh's Stage Center.

3 The Stage Center, Riyadh

The Stage Center is a 30-story mixed-use project, strategically located along King Fahd Road on an 8,250m² plot in Riyadh's Al Muruj neighborhood. To allow for the large spans, cantilevers and irregularities in the structural design, BBR Saudi Arabia employed around 6,000 BBR VT CONA CMF anchorages to hold flat tendons in post-tension supporting the 300t structure.

Post-tensioning saves on concrete costs through reducing the amount of material required, expands spans, and allows for cantilevered projections. The team's implementation of a smart solution underscores the project's commitment to cutting-edge construction methodologies.

The Stage Center is poised to redefine Riyadh's urban landscape, beautifully integrating form and function in high-rise architecture.

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9 STC Smart Square is an ambitious integrated development in the heart of Riyadh.
10 Viewed from a different perspective, the development includes several iconic structures, with open spaces for the building occupants.

4 STC Smart Square, Riyadh

Covering more than 121,000m², this smart development is spearheaded by AQALAT, a subdivision of telecoms company, stc. When complete, at the end of 2024, it will encompass 12 buildings including six towers and a new AI-enhanced hotel. The project in Riyadh City's Al Mursalat district was designed to showcase stc's digital technologies.

Smart Square is packed with physical devices connected to an intelligent building systems command-and-control center (CCC). This links core services, including lighting, power, and water meters, pumps, heating, fire alarms, cooling, elevators, and access control systems. Critical instructions, notifications and alerts are automated. There is also a focus on sustainability with double-skin buildings, low carbon construction materials, and building energy efficiency.

BBR installed 560t of post-tensioning solutions within the flat slab on the project, helping it achieve completion with eight months. Around 11,000 BBR VT CONA CMF anchorages have been seamlessly integrated into the project.

TEAM & TECHNOLOGY

1 JEDDAH ROSE, JEDDAH

Owner/developer – Al Ameen Real Estate Company
Designer/architect – PARALX
Main contractor – Rafiq Kreidieh Contracting Co.
Superstructure contractor/PT design – BBR Saudi Arabia (PT Design)
Technology – BBR VT CONA CMF
BBR Network Member – BBR Saudi Arabia

2 NORTHERN BORDERS MUSEUM, ARAR

Owner/developer – Saudi Commission for Tourism and National Heritage
Designer/architect – Pace
Main contractor – Setco
Superstructure contractor/PT design – BBR Saudi Arabia (PT Design)
Technology – BBR VT CONA CMF
BBR Network Member – BBR Saudi Arabia

3 THE STAGE CENTER, RIYADH

Owner/developer – Al Saedan Real Estate Company
Designer/architect – The AJ Group
Main contractor – First Saudi Contracting Company
Engineering Consultant – The AJ Group
Superstructure contractor/PT design – BBR Saudi Arabia (PT Design)
Technology – BBR VT CONA CMF
BBR Network Member – BBR Saudi Arabia

4 STC SMART SQUARE, RIYADH

Owner/developer – AQALAT
Designer/architect – Saudi Consulting
Main contractor – BEC Arabia
Superstructure contractor/PT design – BBR Saudi Arabia (PT Design)
Technology – BBR VT CONA CMF
BBR Network Member – BBR Saudi Arabia

Global
Selecting post-tensioning technology strategies for tanks and silos

Not every tank is created equal

The world needs more tanks and silos built to store, shelter and protect a growing population. Spaces are required for energy, food, water, goods and the materials for the built world – spaces that are constructed using minimal carbon yet are still fit for purpose. With the right strategy, post-tensioning technologies can play a role in delivering these tanks and silos.

Three experts from SRG Global, Sam Pearce, Roger Stables and Mark Sinclair, share their experiences of what makes a good tank strategy.

Global megatrends are driving the need for more tanks and silos

The global demand for tanks and silos is growing at between 3.5% and 4.8% annually. Analysts predict this market expansion will speed up into the 2030s, as demand drivers rapidly accelerate.

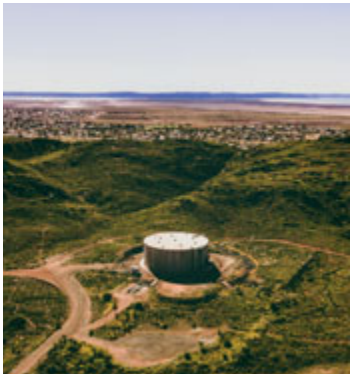
Behind this growth in tank and silo construction are megatrends like population growth, industrialization, urbanization and evolving geopolitical instability, alongside climate change. More people means greater demand for energy, food, plastics, chemicals and construction materials for the plants and infrastructure required. Urbanization concentrates people away from areas where food and goods are produced. Political instability and conflict mean generating, moving and storing energy in new ways and places. Climate change is fundamentally changing ecologies and water cycles and driving low-carbon and renewable energy technologies.

The impact of these megatrends is a need for more energy, food and water storage facilities, petrochemical plants, cement works and further infrastructure requiring more containment and storage. These tanks and silos must be built with technologies that minimize material consumption and environmental impact, while ensuring they are fit for purpose.

1

2

1 Al-Zour LNG Import Terminal in Kuwait during construction of eight LNG tanks in 2019. Each tank is 225,000m³, 90m in diameter and 45m high and is one of the world's largest LNG terminals. They were constructed in temperatures which topped 50°C in a coastal environment.
2 Tanks designed for specific applications, all using post-tensioning. Top: Aggregate silos at Shellharbour, Australia, designed to contain bulk dry solids. Middle: Potable water tank near Merredin, Australia, designed to contain liquid without leakage. Bottom: Wastewater treatment digester near Perth, Australia, designed to contain sludge under pressure.
3 The Karratha water tank, located outside Karratha, Australia. The remote site location is far from construction infrastructure, such as cement plants. The side and roof panels were pre-cast and shipped to the site for assembly.



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Formulating a tank strategy – design considerations

Multiple factors should be considered at the design stage before the construction method is considered. The factors will vary from application to application and will include some or all of the elements listed below;

- Material to be stored
- Storage volume
- Temperature and product density
- Frequency of loading and unloading cycles
- Community safety risks associated with material being stored
- Working life requirement
- Site location and durability needs
- National Standards and best practice
- Construction methodology and duration prior to entering into service
- Client experiences with potential storage solutions
- Initial cost of construction
- Future maintenance costs

How complex is your tank?

The complexity of a project is on a continuum. Some tanks may be passive materials silos used for dry solids like grain or sugar silos, clinker silos in a cement plant and dry chemicals. In this case, passive reinforcement may meet the application, design, build and budget requirements. More complex design considerations are required for applications like liquid storage. This could be materials like water, slurry, chemicals, petrochemicals and crude oils. These tanks may also have more complex features because of what is being stored, from basic leak proofing through to fire suppression. In the case of waterproofing or blast resistance, active reinforcement using post-tensioning may be the optimal solution.

At the most complex end of the design spectrum are storage and containment structures for applications such as storing liquid petroleum gas (LPG), liquid natural gas (LNG) and for nuclear power plants. These tanks will have additional requirements, such as fire suppression, medium and high-pressure storage, cryogenic storage and for containment in the event of a blast. Tanks designed to hold compressed gas at low temperatures need to withstand steep thermal gradients and shock loading.

They may be part of a containment system so if there is a rupture of the primary tank, the secondary tank contains the spill. Or a sacrificial containment structure to protect against blast, acting as a wall to deflect the force of the blast upwards. At the top end are regulated nuclear containment structures designed to contain huge forces and prevent the escape of dangerous substances. Contrast these applications to the first example, a passive grain silo designed to keep its contents contained and dry.

Conditions, location, speed and costs

Temperature conditions can impact design considerations for the construction. The Al-Zour Import Terminal in Kuwait, shown opposite, was built in a coastal setting with high temperature ranges, averaging 50°C during the day (see CONNÆCT Edition 14 pages 66-67). To keep the grout mix at the right temperature, 6t of ice was needed daily, and most of the post-tensioning work, especially the grouting was completed at night.

Location also impacts approach. The Karratha water tank in a remote part of Australia more than 1,500km north of Perth required all its materials trucked in. This favored an approach using pre-cast components, for the wall panels and roof compared to cast in place concrete.

Speed is another consideration. Temporary storage structures typically need building quickly and taking down, so the approach must accommodate rapid assembly and disassembly.

The financial and environmental costs will be a key influence on the design and approach. BBR VT Co-Chairman, Bruno Valsangiacomo, notes in his introduction (pages 6-11) that asset owners increasingly combine the two. The sustainability of the built asset partly determines its value. This means low carbon design approaches and construction technologies will increase the value of the tank, as well as its performance.

Design considerations for tank and silo MRR

As BBT VT International's CEO Olivier Forget highlights in his business review (pages 18-19), often the lowest carbon structures are the ones that are already there. This is true of tanks and silos. Aging infrastructure in advanced economies, or facilities built with lower specifications in fast-growing economies with higher demands, can benefit from MRR over replacement. There are approaches and technologies, including post-tensioning, that are particularly suited to strengthening and repairing existing tanks and silos. ›

Post-tensioning benefits for tank and silo construction

The application and design considerations will determine which approach and construction technology is used when building a new tank or silo, and when maintaining and upgrading existing structures. Post-tensioning as an approach to constructing tanks and silos has multiple benefits: reduced materials, speed, and the flexibility to be more creative with structures. Post-tensioning also brings specific benefits to the design and construction of tanks and silos, making it suitable for more complex tank and silo structures used for fluids in general and low temperature pressurized fluids specifically. Tanks and silos that do not use post-tensioning require a significant amount of passive reinforcement due to the internal stresses on the walls. Materials reduction is a benefit, but in the case of tanks and silos, it is significant.

PT in action – flexibility

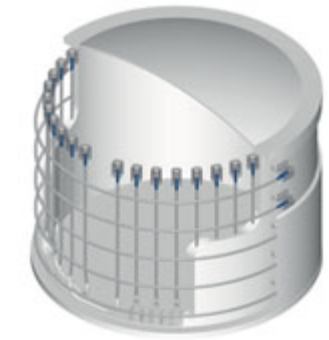
PT in tanks is typically circumferential horizontal hoop tensioned, vertically post-tensioned or both. The tendons can be dead-end anchored within the walls or, in the case of horizontal tendons, tensioned at the buttresses. The exact configuration depends on the application and design configurations, but PT can meet most design needs and integrate with passive reinforcement.

Grain silos using PT may be vertically post-tensioned as they tend to be tall, narrow structures. Stiffness and reduced deflection are a consideration. However, for dry solids (grain and cement) silos, crack width control is generally less of an issue. In contrast, an LNG tank's contents are pressurized, and the solution may require double or full containment so it will likely feature both vertical and horizontal PT to perform multiple functions.

How PT integrates with construction methods

As many silos are tall structures, slip-forming and jump-forming are common approaches, particularly for rapid construction. Slip-formed circumferential hoop tensioned PT is one option for fast construction, as the tendon ducts are laid as the walls are built, enabling the tendons to be subsequently threaded and stressed. Slip-formed PT allowed SRG Global to complete the Gladstone cement silo in five weeks, meeting the tight project deadline.

Where an isolated location favors pre-cast concrete wall, floor and roof slabs, such as the Merredin and Karratha water tanks, PT can be more effective than other solutions. The slabs are thinner, so less concrete and passive reinforcement is used. Recycling formwork is time consuming and offsite precasting means reduced onsite concrete placement is necessary, saving time. Stressing the tendons compresses the concrete and closes the gaps between pre-cast slabs, improving integrity and minimizes leakage. By using PT, the elements can be thinner, use less material and be lighter, which minimizes transport resources and lowers emissions.



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4 How flexible is post-tensioning when applied to tank construction? This figure shows horizontal and vertical tendons with dead-end anchorages, applied in many applications, such as LNG tanks. Depending on the design considerations, the tank may use only horizontal post-tensioning.

5 Post-tensioning pre-cast panels showing tendon ducts, used for the water tank near Merredin, Australia. Post-tensioning allowed for thinner slabs with less concrete and reinforcement, less weight to transport to the remote site, and less carbon. The cost benefits of the solution were instrumental in the choice of construction. Post-tensioning also compresses the concrete and the joints between slabs, improving waterproofing.

6 Slip-formed 15,000t capacity powder storage silo. At 53m high, and a deadline of only five weeks, this was the best approach, incorporating BBR VT CONA CMI internal post-tensioning. Main contractor John Beever Australia commissioned SRG Global to complete slipform and post-tensioning works for client Cement Australia at their Fisherman's Landing facility in Gladstone, Queensland.

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7 LNG tanks being constructed in 2010 at the ENAGAS terminal in Barcelona, Spain. These tanks feature both horizontal and vertical PT.
8 The post-tensioning stressing process compresses the pre-cast concrete wall slabs. This waterproofs the joints between the slabs, reduces the porosity of the concrete, and limits seepage through the tank walls.
9 This aerial shot of the Merredin water tank base slab pour is a reminder of the role the tank base has in maintaining integrity. As the tank walls are tensioned, there will be movement between the wall and the base, which must be considered when sealing the tank.

Sealing and leak proofing

Concrete is porous and can crack and can cause leaks, and points of stress concentration that could lead to structural failure, and therefore containment loss. When stressed, the PT tendons compress the concrete. This controls cracking, improves adherence of adjacent slab surfaces within the joints, and reduces porosity. These features mitigate the risk of leaks and containment loss. There are other waterproofing and sealing technologies that can work with PT, such as polymer coatings, that further enhance the integrity of the tank, particularly if liquids are chemically active.

Cryogenic solutions

The natural gas in LNG tanks kept at cryogenic temperatures of -196°C through auto-refrigeration. The LNG tanks at Barcelona's ENAGAS terminal will operate in an annual ambient temperature range of 8°C to 29°C. At the Al-Zour Import terminal, daily temperatures reach 50°C. The thermal gradient between the tank interior and exterior can be huge. The high-grade steel used in PT tendons experiences a strengthening effect at cryogenic temperatures. Research by BBV VT has shown that failure occurs at the tendon side under ambient temperatures. The BBR VT CONA CMI internal PT system operates normally under temporary and permanent cryogenic conditions, with only normal grade anti-bursting reinforcement, giving a considerable material saving.

Corrosion protection

High levels of corrosion resistance are required for all tanks and silos but specifically for tanks that contain chemically active fluids, such as LNG or LPG tanks. PT tendons are typically encapsulated within plastic ducts filled with cement-based grouts. These contain additives that protect against corrosion. The BBR VT CONA CMI internal PT system includes an advanced electrically isolated tendon (EIT) solution which prevents chloride and electrochemical corrosion of the steel.

Reduced maintenance

There are a wide range of features intrinsic to PT systems that reduce the maintenance need of a tank or silos using the technology. For example, the encapsulation of the PT tendons in protective grouts and advanced EIT solutions highlighted in the section above can reduce or eliminate corrosion. Post-tensioning produces active concrete crack control, which limits maintenance requirements by preventing the structural damage and material loss associated with cracking. It can also protect passive reinforcement from corrosion by water and other fluid ingress via concrete cracks.

Integrating PT strategies early

As with all engineering and construction disciplines, there are details and insights that only an expert will know. This article provides an overview of many of the key factors to consider when developing storage and containment solutions like silos and tanks. All three experts stress the need for the PT contractor to be part of the design team from the outset.

Speaking early with the consultants who are designing the tanks and being part of the design consideration process from the beginning, allows for experience and expertise sharing. This adds value to the project and the end-client.

ÆVIA – Etablissement Câbles et Manutention
Rufisque, Senegal
BBR VT CONA CMI internal for cement plant

Cementing Senegal's future growth

ÆVIA horizontally post-tensions two silos for a new cement plant

A new cement production line is under construction in Rufisque on the outskirts of Dakar. BBR Network Member for France ÆVIA's Antoine Dupre explains how, as an alternative to classic reinforcement, BBR post-tensioning maintains the integrity of two of the plant's huge silos, saving concrete and carbon.

Senegal's economy is enjoying near-double digit growth, and the country is expanding its infrastructure and industry to support this. Leading Senegalese cement manufacturer SOCOCIM Industries, a subsidiary of French cement group Vicat, is building a new 6,500t per day cement plant. Situated alongside an existing plant at Rufisque, on the outskirts of the capital Dakar, the new plant will double the site's output, helping to fuel the country's growth by supplying materials to support the construction boom.

The new plant features two large concrete tanks: a taller and thinner 70m high by 23m diameter clinker silo and a shorter, broader 50m high by 35m diameter silo to store cement after production and before bagging. ÆVIA was commissioned by main contractor Eiffage Sénégal to design and install a BBR VT CONA CMI BT internal horizontal bonded strand post-tensioning system to maintain structural integrity. ÆVIA project managed and delivered the post-tensioning element, providing expert advice on post-tensioning to the main contractor. This included completing the preparation, acquiring the jacks, scaffolding and 330t of BBR VT CONA CMI steel strands and couplers with grouting, as well as shipping the materials from France, Spain and Italy to the site in Rufisque.

Threading silos with multi-strand tendons

When ÆVIA arrived on site in spring 2023, construction activity was underway, and space was at a premium. With the silo foundations in place and the concrete tank walls completed, constructed layer by layer with climbing formwork, the ducts and anchorages for the tendons were inserted into each layer during the concrete casting process.

1

The clinker silo features six buttresses housing the tendon stressing anchorages, while the storage silo has four buttresses. Across the two structures, there were three types of tendons: nine, 12 and 13-strand tendons. These tendons had been selected according to the internal loads, so the storage silo features nine and 12-strand tendons and the clinker silo features 12 and 13-strand tendons.

In May, work started on threading the clinker silo with the tendons for post-tensioning. Supported by a tower crane, the local team installed a load-bearing strut with an elevator winch at the top of each buttress from which a cradle was suspended, allowing the site crew to access the buttresses. Starting from the silo base, the crew threaded the tendons into the concrete ducts via the strand anchor points in each buttress, as the cradle was winched progressively higher up the silo wall.

The tendons ran internally from buttress to buttress, awaiting post-tensioning. The clinker silo required 288 tendons, with the storage silo requiring 156 tendons.

Delays and duct realignment

During the threading process, the site crew noticed some resistance to the tendons. Further investigation revealed that not all the internal ducts were aligned. When the silo wall was constructed, the concrete had set unevenly. This caused duct misalignment, preventing the tendons from completing the journey from buttress to buttress.

Remediation work was required, and this led to delays – delays that were made worse when political tension caused a shutdown in mobile telephone and internet communications. This made team communication difficult, but ÆVIA had worked under unusual conditions before, and work continued.

Despite this, the duct misalignment and loss of communication disrupted the threading process, which left the tendons exposed to Rufisque's dry and dusty coastal climate. The site crew had to lubricate the tendons to protect them from corrosion during the disruption, and before the grouting stage.

Post-tensioning the silo tendons

Threading the storage silo was completed in September and early October, when post-tensioning began. The post-tensioning technology chosen by ÆVIA was BBR VT CONA CMI BT internal bonded solution. Having threaded the tendons, the next stages were anchoring, post-tensioning and then grouting.

Why post-tensioning over classic reinforcement?

The plant silos are large and designed to contain dense materials. The combination of the structure and its contents generates high outward pressure and internal stresses. Traditional reinforcement approaches would require the concrete walls to be two to three times thicker to accommodate this internal pressure and allow the silo to support its own weight.

Post-tensioning technology provides the required strength for a much thinner wall. This significantly reduces the amount of concrete used in construction. This cuts costs and the overall carbon cost of the structure.

2

3

4

1 The new cement plant will support new infrastructure for Senegal's growing population.
2 The cradle is suspended from a strut with a winch, raising the cradle as each strand is threaded.
3 Dusty strands on the tendons inserted early in the threading process.
4 The strand anchors set into the side of each buttress. The tendons are threaded into these openings, although it was discovered some of the ducts required realignment.

TEAM & TECHNOLOGY

Owner/developer – SOCOCIM Industries
Designer/architect – Fives FCB
Main contractor – Eiffage Sénégal
PT design – ÆVIA
Technology – BBR VT CONA CMI BT internal
BBR Network Member – ÆVIA (France)

Contech
Auckland, New Zealand
MRR range for Princes Wharf

Defying the challenge of age

New Zealand's Contech has a decades-long relationship with Ports of Auckland. It started back in 1995 with a commission from the port's management to undertake extensive concrete remediation at its Jellicoe Wharf.

The team has since completed multiple repair and maintenance projects at eight of the port's wharves. But the latest to date, at the historic Princes Wharf, introduced a new level of complexity, solved using MRR. It was to become one of the company's top five largest projects.

Almost a century of performance

Princes Wharf, named after Edward, Prince of Wales, was formally opened on 12th May 1929 by Jellicoe, the then Governor-General of New Zealand. Its two-storey concrete structure was a first for Auckland, as all previously constructed wharves had used a single-storey, shed design.

The wharf had a key role in World War Two, when it was placed under the control of the United States Armed Forces to provide provisions to the Pacific War. When the war was over, it provided an important departure and destination point for ocean liners and later cruise ships.

In 1960, the port began offering passenger services – an innovation that proved so successful that a dedicated passenger terminal was built on the wharf.

Changes continued. Today, the wharf hosts the recently renovated Overseas Passenger Terminal (a cruise ship berth managed by Ports of Auckland), and above it, a nautically-inspired, 80-floor, 120,000m² building that houses upmarket bars and restaurants and a five-block, luxury Hilton Hotel and 400 apartments, as well as office space, a multi-story car park and 400m² of deck space.

1

2

3

1 Auckland's Princes Wharf and Viaduct harbor area feature a busy hospitality, retail and residential environment, as well as a cruise ship mooring.
2 Contaminated concrete removed from the wharf structure.
3 Contech's team worked in cramped conditions to repair the wharf pilings.

TEAM & TECHNOLOGY

Owner/developer – Ports of Auckland
Engineer – Beca Ltd
Main contractor – Contech
Technology – MRR range
BBR Network Member – Contech

A challenge with multiple dimensions

Contech's role was to restore the 100-year-old wharf so it could continue to provide the service required for this busy and important structure. However, the project's implementation was always going to be challenging, for three significant reasons:

1. The concrete wharf piles, beams and deck were badly damaged due to their location in a harsh, high-salt, high-chloride environment. The repairs would be extensive and undertaken in an area of tides, high winds and rough seas.
2. The machinery required would be noisy and this would impact on the people living and working in the hotel and apartment complex, and on those passing through on cruise ships.
3. The scale of the wharf was enormous, with six piers, 800 columns and a total area of 160m^3. The project would keep the Contech team of 25-30 busy for 17 months five days a week between May 2022 and October 2023.

However, the solution to the problem was relatively straightforward for the Contech team. They used hydro- demolition to remove chloride contaminated concrete from the elements and rebuilt them with a high-strength dry spray concrete – a tried and tested process.

Managing site-specific issues

Mark Kurtovich, Contech's Business Development Manager, described the noise as being one of the most challenging aspects of the project, one that required effective project management, clear communication and on-site diplomacy.

"Managing the effects of project noise on communities with which we work has always been an integral part of Contech's service," Kurtovich says. "In this case, it was more important than ever that we organize our work schedule around those most likely to be affected."

So, the planning work started early.

"We began by identifying the issues and planning ways to resolve them. Getting the basics right can be as simple as arranging our work so that as few people as possible are affected, and those who are know what's happening and can make decisions based on that knowledge. We know we can't please everyone all the time, but we do our best to get close, Kurtovich adds."

The Contech team, in partnership with Ports of Auckland, worked closely with key representatives of the hotel, apartments and commercial businesses, as well as affected parties in sounding areas, to develop and deliver an action plan. This included:

- providing those likely to be affected with as much information as possible, including on the nature of the work, the equipment and the hours of operation
- identifying and measuring noise sources, levels and durations and the people/businesses most likely to be affected
- scheduling the noisiest work at times that affected as few people as possible. For example, the team scheduled work in the restaurant areas to take place in the early mornings in winter, when doors and windows were closed
- having a strategy to deal with complaints, and a person for people to talk to.

Kurtovich notes that Contech is committed to finding new ways to reduce the impact of noise and debris during projects, including ways to reduce its carbon footprint: "We know we inevitably test peoples' patience on projects like this. We do everything we can to mitigate that while ensuring our teams can work effectively in what can be extremely challenging environments."

Contech
Tokoroa, New Zealand
MRR range for mill building

Danger and safety at Kinleith Mill

In 60 years of service, Contech has completed an array of projects for clients, but it's not often been presented with the challenge of operating in a potentially toxic environment in which the client's employees must continue their work with minimal disruption.

1

This was the situation in April 2023 when Kinleith Mill, which operates at the heart of New Zealand's pulp and paper industries, required repair work. MRR technology proved the solution.

Contech was approached to repair several concrete structures in a building integral to the mill's business. Given the dangers of the work and the poor performance of the preceding supplier, it would be a trial three-month contract with the potential for more – a challenge the team accepted with alacrity.

Part of a community

Kinleith Mill occupies 60ha of land near the town of Tokoroa in an area that sits between the lush farmland of Waikato and the vast plantation pine forests of the central North Island. The mill has been part of the Tokoroa community since 1953 and is currently operated by Oji Fibre Solutions, one of Australasia's leading manufacturers of pulp, paper and wood-fibre-based packaging solutions.

The company is Tokoroa's largest employer, with around 450 employees and 280 subcontractors. It produces around 330,000t of packaging per year and 265,000t of mainly bleached softwood pulp.

The mill has long had a commitment to reducing waste through efforts such as treating used water and returning it to the catchments. It also has its own cogeneration plant, operated by Genesis Energy, New Zealand's largest electricity retailer by market share, which burns wood waste and generates approximately 40mw of electricity that is used mainly on site. In its 2013 environmental sustainability report, Oji Fibre Solutions stated that it was now generating 47.9% of its electricity needs from renewable sources and, in conjunction with a sister mill, had used 219,515t of recycled paper in the paper making process.

Accepting the challenge

For this project, Contech's role was to repair 6m^3 of corroded concrete at the mill's chlor-alkali plant. This is a major hazard facility that, as part of Kinleith's commitment to waste reduction, uses salt and electricity to recycle by-products of the milling produce into chemicals and materials such as chlorine, chlorine dioxide, turpentine and hydrogen peroxide. For both the Contech team and Kinleith's employees on-site, it was a dangerous place to work in which everyone was required to wear special protective and emergency escape equipment and be fully trained in emergency response and management.

The latter included a strict requirement for the team to comply with the safety requirements at Kinleith Mill, which document its safety management system, hazard identification and risk assessment processes, and emergency response planning. It also highlights all potential major incidents and the controls in place to minimize the risk of incidents as far reasonably practicable. A major incident was defined as 'an uncontrolled event at a major hazard facility that involves specified hazardous substances and exposes multiple persons to a serious risk to their health or safety'.

It was here that Contech's extensive experience in the building industry proved its worth. As well as complying with Kinleith's safety case, the team was able to adapt their own, proven model to the client's requirements and Kinleith's dangerous working environment.

This often meant going beyond standard practice by, for example, developing a rigorous induction programme with a focus on personal and group safety, providing online pre-arrival sessions, and holding daily briefings to ensure everyone had the information they needed to stay safe while doing their job. With multiple projects to be completed, coordination and cooperation would be key to success.

Delivering the goods

Contech's team of five to six (depending on workloads) were typically scheduled to undertake standard concrete repair work, including hydro-demolition, reinforcement replacement and repairs and re-casting. To ensure consistency and continuity, each operated according to a cycle of on-site work every day for two weeks, staying overnight in nearby Tokoroa, then going home for a weekend before heading back again.

To the team's delight, their commitment to performance excellence and willingness to work beyond the norm in a stressful environment were rewarded with the satisfaction of a job well done. The result: a vastly improved working environment for Kinleith's chlor-alkali crew, a successful investment for the Kinleith client, and another job well done for the Contech team.

2

3

Radiata pine in New Zealand

When Europeans arrived in New Zealand in the mid-1800s, much of the country was covered in native forests and shrublands. However, many of the forests were cleared for sheep, cattle and dairy farms, and the timber was used to build towns and farm fences.

Today, about 2.1 million of New Zealand's total land area of 26.8 million ha is planted in production forest with the goal of harvesting its timber and carbon credits for profit, and of that, around 90% is planted in radiata pine. The remainder are Douglas fir (60%) and other softwood and hardwood species. 96% of the plantation forests are privately owned and used for commercial timber production.

1 Kinleith Mill and cogeneration plant has been a huge feature of daily life in Tokoroa since 1953.
2 Removing corroded concrete at the mill, where every site operative was required to wear special protective equipment.
3 Concrete repair work at the plant.

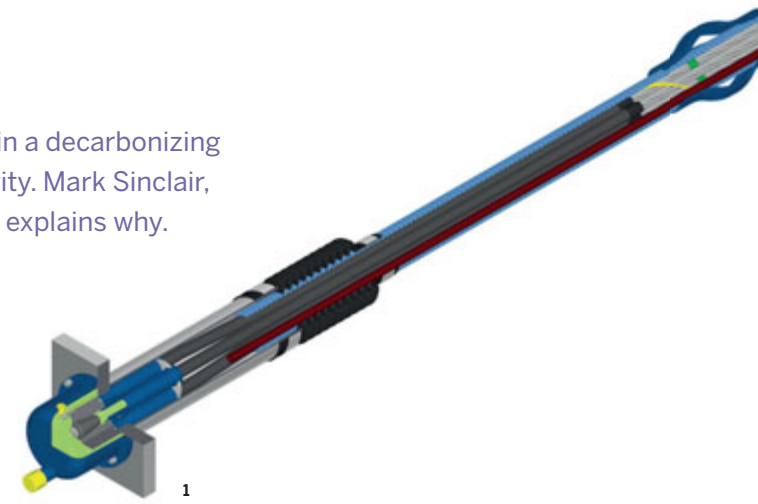
TEAM & TECHNOLOGY

Owner/developer – Oji Fibre Solutions
Post-tensioning contractor – Contech
Main contractor – Contech
Structural engineers – Beca Group Ltd
Technology – MRR range
BBR Network Member – Contech

Global
The importance of monitoring strand ground anchors used to strengthen dams

Dam right

Dams play an important role in energy generation, especially in a decarbonizing world. Regular safety checks ensure ongoing structural integrity. Mark Sinclair, General Manager of Engineering and Technical at SRG Global, explains why.



1

As the physical manifestation of humankind's dominance over nature, few structures beat dams. Dams provide water storage and enable power generation and flood prevention. A dam's failure can damage life, property and energy generation capacity.

2

In September 2022, insufficient maintenance of the Derna dam in Libya led to its collapse during Storm Daniel, killing up to 20,000 people. To prevent this, and increase the infrastructure's structural capacity, concrete dams often undergo post-tensioning with steel tendons. This occurs either at the point of construction or as part of an upgrade. Depending on the anchor's purpose, maintaining the loading within the tendons is essential to a dam's structural integrity. Regular performance checks are required for permanent ground anchors. These are installed through the dam structure and inserted deep into stable geological foundations.

Regular monitoring

Anchors require regular monitoring by assessing the tensile load they are carrying. Visual inspections identify any degradation. Over time, the residual load decreases due to stress relaxation within the steel tendon or foundation load transfer conditions. A sudden, unexpected change could indicate the anchor's deterioration, which could lead to leakages, instability and even catastrophic failure.

Measurement is installation specific. A permanent load cell is based on strain gauge technology, and these convert force into a measurable electrical signal. Within each load cell there are multiple strain gauges made of thin, flexible stainless steel. Load compressing the cell deflects the strain gauges and changes the electrical resistance. The load cell, which is calibrated to a readout device, uses this electrical change to display a value which can be correlated to the anchor's residual load. When assessing the results, care should be taken with permanent load cells that can't be replaced as their life expectancy is less than the permanent anchor. An alternate monitoring option should be integrated in the design if the load cell reading is in doubt.

3

Trust the expert

Mark coordinates teams that monitor dam anchors constructed by SRG Global. For Mark, familiarity with the dam's behavior and anchor construction aids in understanding any variances observed during anchor testing.

Monitoring post-tensioned dams is a complex but critical task, requiring skilled engineering judgment and expertise. Given the importance of these structures, specialists like Mark play a vital role in their safety and functionality.

1 The BBR VT CONA CMG system strand ground anchor is certified up to 100 years' use.
2 SRG Global strengthening the Keepit Dam in New South Wales, which included installing 67 permanent ground anchors.
3 Mark Sinclair, SRG Global's 'dam king', on site at the Hazelmere Dam standing next to a jack stressing ground anchors, Durban, South Africa.

Finding the rhythm

Dam monitoring schedules vary between projects and jurisdictions, but a typical schedule involves:

- Initial test loading and anchor force locking off: Sets the baseline load data.
- Early checks: Assessing the anchor's residual force two days after stressing and again at 28 days.
- Intermediate assessments: At 12 to 24 months depending on regulations or client requirements.
- Long-term evaluation: Checks at five yearly intervals to assess any significant load decreases or condition changes.

The Hazelmere Dam in Durban, South Africa, became a record-breaking structure following the installation of 83 permanent ground anchors by SRG in 2017 (see CONNÆCT 2023 pages 66-69). Residual load monitoring is a key element of this project.

BBR Adria d.o.o.
Samobor, Croatia
BBR VT CONA CMI reinforcing a church bell tower and walls

Seismic retrofit and upgrade of a historic bell tower

After two earthquakes struck Zagreb in 2020, nearly 60,000 buildings were damaged, including the Church of the Assumption of the Blessed Virgin Mary in Samobor just outside Croatia's capital.

Many heritage buildings were damaged in the earthquake, including churches where the bell tower, roof, vaults or perimeter walls collapsed. The Church of the Assumption of the Blessed Virgin Mary was damaged but thankfully not destroyed. In summer 2023, BBR Network Member for Croatia, BBR Adria, strengthened the bell tower and walls with internal post-tensioning.

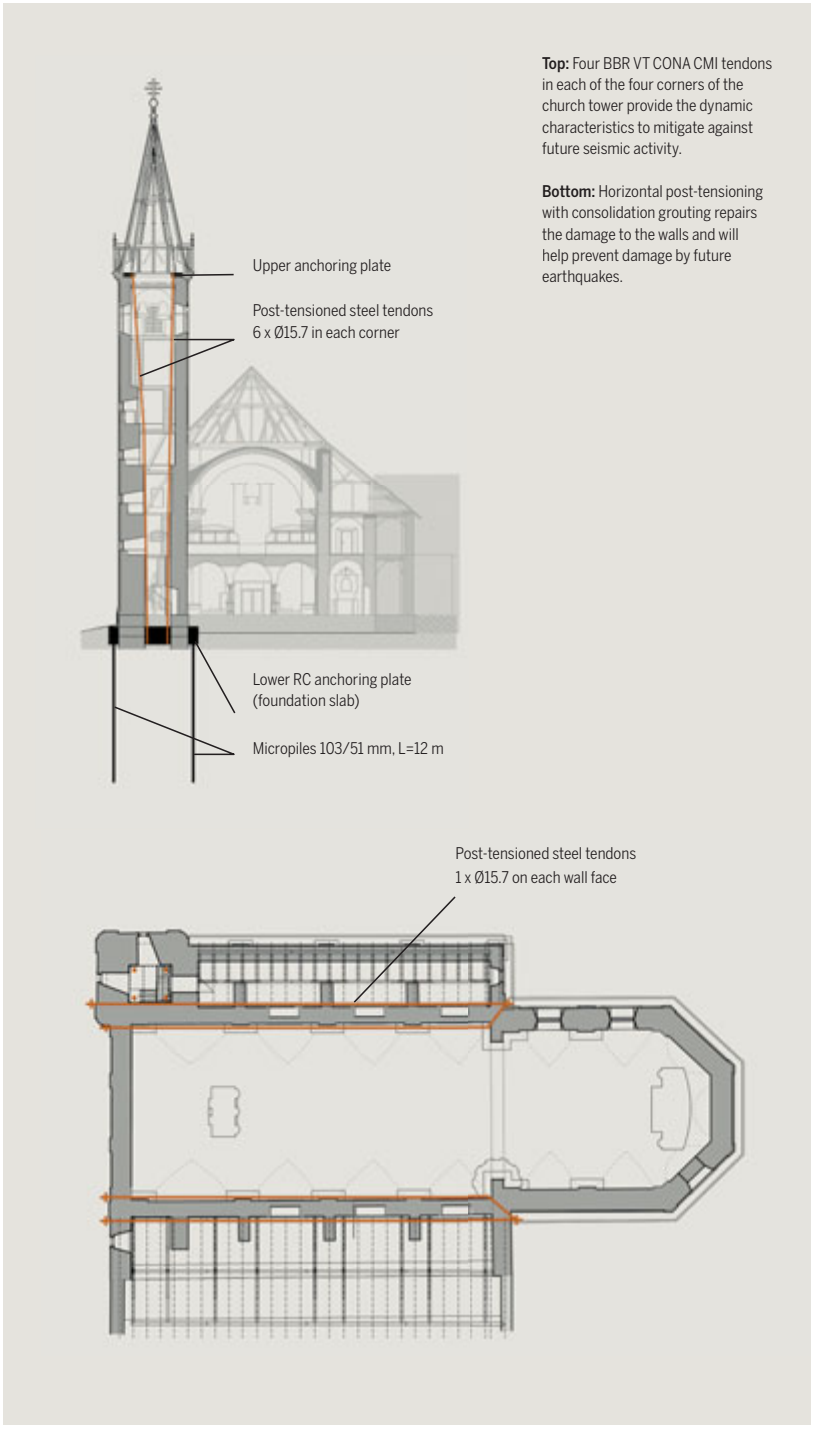
1

The Church of the Assumption of the Blessed Virgin Mary is near the center of Samobor, a town of almost 17,000 people. The church that stands today was built around 1733. It was originally part of a 13th century Franciscan monastery complex, in which it remains situated today. It is a 38m-long and 20m-wide single nave building with side chapels. On the northwest corner is the 42m high bell tower, with a footprint of 5.1m by 5.2m. Undressed rough stone, or rubble masonry, is the main structural material of the walls and vaults.

Seismic induced pounding causes cracks

When assessed following the earthquake, the structural damage was classified as 'heavy', meaning there was moderate structural damage with heavy non-structural damage. Most of the structural damage was detected at joint walls between the church and bell tower. As the bell tower walls and the church walls have different stiffness characteristics, the force of the earthquake resulted in seismic pounding, or a collision hammering effect.

During the 18th century, expansion joints were relatively unknown. As a result, the church wall as the weaker element suffered a 150mm-wide vertical crack from the seismic pounding. The barrel vault underneath the timber roof was also heavily damaged.



Top: Four BBR VT CONA CMI tendons in each of the four corners of the church tower provide the dynamic characteristics to mitigate against future seismic activity.

Bottom: Horizontal post-tensioning with consolidation grouting repairs the damage to the walls and will help prevent damage by future earthquakes.

Assessing if the church can be salvaged

The retrofitting planning process began with an assessment to address what damage needed the most urgent attention. A detailed assessment was completed using specialized surveying tools, such as laser scanning. This data provided insight into the heritage properties of each individual building and allowed the team to build a BIM model.

From the BIM model, the team built an elegant solution that included internal post-tensioning. This would repair the existing structural damage and strengthen the church walls and tower against damage from future seismic activity. Unlike many traditional solutions, internal post-tensioning had the added advantage of not disrupting the clean lines of the historic building's design.

This structural modeling and analysis based on data and a retrofitting proposal had to be approved by the Conservation Department inside the country's Ministry of Culture.

2

A repair and upgrade solution

A technical retrofit and upgrade solution was installed in the church bell tower that introduced vertical post-tensioning of the external walls with BBR VT CONA CMI seven strand tendons, each with an overall tensioning force of 600kN. Before this procedure, the stone masonry walls were consolidated with grouting and steel anchoring. This will prevent future delamination – the most common cause of deterioration and collapse in historic stone masonry.

Within the church tower, to provide anchor points for the post-tensioning tendons, a reinforced concrete foundation plate with vertical micropiles was constructed. Several horizontal steel diaphragms for torsional stability were then erected inside the bell tower.

Alongside the bell tower work, the church was partially upgraded with horizontal post-tensioned BBR VT CONA steel tendons embedded in the main walls of the central nave. This major project on a historic heritage building marks six decades of success for BBR Adria.

1 Crkva Uznesenja Marijina (The Church of the Assumption of the Blessed Virgin Mary) and monastery in Samobor was built around 1733.
2 Four internal tendons were used to both restore the church tower and provide structural rigidity in the event of future seismic activity.

TEAM & TECHNOLOGY

Owner/developer – Ministry of Culture, Croatia
Designer/architect – Studio Arhing
Main contractor – SPEGRA
PT design – BBR Adria
Technology – BBR VT CONA CMI
BBR Network Member – BBR Adria

BBR Saudi Arabia
Riyadh, Saudi Arabia
External PT, FRP, rebar reinforcement, jacketing for MRR/hospital, KSA

Intensive care for a Riyadh hospital

Khurais Hospital in Riyadh, previously a hotel for nearly ten years, required structural enhancement for its new, caregiving role.

The BBR Saudi Arabia team assessed the building's concrete strength through core sampling and found it inadequate for the new use incurring an approximate double load of heavy beds and medical machinery.

The building's walls, columns, slabs all needed reinforcement to increase the building's ability to resist bending stress. Worsening matters was "bunching" (see box) around the columns which threatened to penetrate the floor slab.
The BBR team jacketed the wall, columns and slab with a thin layer of screed within which they applied: carbon fiber-reinforced polymer (CFRP) strips around columns; rebar to the column shaft with increased concrete; and PT tendons in the underside of slabs to reduce deflection. They also recapped the column drop panels.
This combined approach not only efficiently addressed the structural challenges but also enhanced the building's longevity.

Too much of a good thing

Reinforced steel bars (rebars) help strengthen concrete slabs and columns. But setting them too close to each other can have the opposite effect. Where this "bunching" occurs, it can be difficult to pour concrete or remove air pockets during the process of compaction, usually achieved with vibration. Uneven or spongy concrete can severely impact the structural integrity of the slab and the ability of the columns to sustain that load as well as resist seismic forces.

TEAM & TECHNOLOGY

Owner/developer – Horizon
Main contractor – Horizon
PT design – BBR Saudi Arabia
Technology – External PT with FRP
BBR Network Member – BBR Saudi Arabia

CFRP strips were secured next to columns to help reduce the risk of punching through. The anchorage and tail of the PT tendons used to prevent floor slab deflection can also be seen.

The drop panels of the columns were re-capped and the columns reinforced with rebar then jacketed with a thicker concrete layer.

PT tendons on the underside of slab before refinishing. These are designed to prevent deflection of the floor/ceiling slab when under load from the floor above.

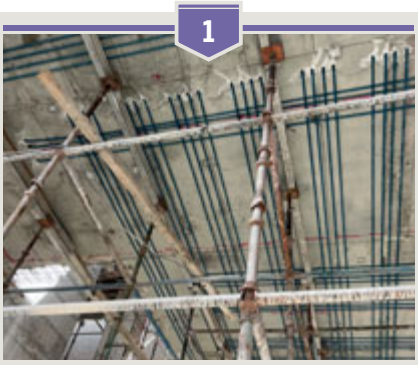
Global
How external post-tensioning technologies are used to strengthen existing structures

External PT, a highly efficient and effective tool in strengthening projects

It's estimated that 50% of a building's lifetime carbon footprint is accrued during construction. MRR of existing built assets is a key strategy for emission reduction. External PT and other reinforcement solutions such as carbon fiber-reinforced polymer (CFRP) further extend the lifespan of structures as well as increasing structural strength for repurposing for change of use.

In this section, we look at some real-world examples of how external PT can be used on its own or alongside other solutions to reinforce existing concrete building elements, thus avoiding the need for slow and carbon intensive rebar-and-formwork interventions.

1



External PT is ideal for controlling deflection without overly increasing weight when refurbishing wide-span structures such as this mall building.

PT solutions are quicker to install than concrete jacketing with rebar and no formwork or extended curing time is required. This is because a thinner layer of screed is required.

2

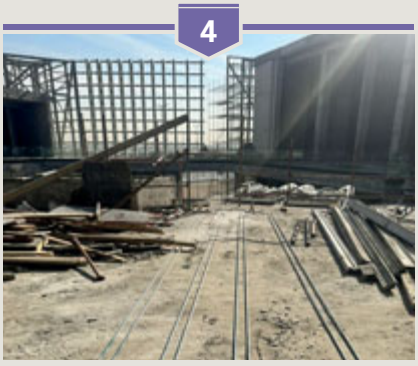
Anchorages and tails protrude from the topside of refurbished slabs. BBR solutions allow for highly precise calculations in deflection control through application of post-tensioned forces.

3

Application of external PT is advised where loading ramps need reinforcement as in this case. The finished slope can withstand heavy equipment and frequent use.

The quick installation time avoids extended periods of downtime which are impractical in a busy facility.

4



The addition of PT tendons minimizes deflection and the risk of cracks appearing in the structure due to impact.

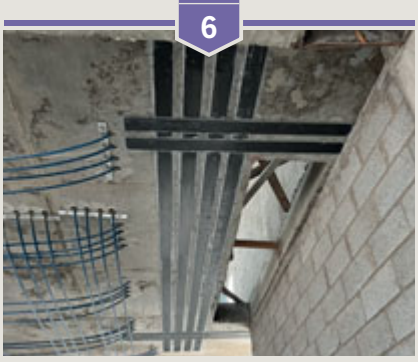
The life of the ramp is extended and the requirement for maintenance is reduced.

5

Where a structure has complex reinforcement needs, external PT can be used in combination with other methods.

In this example, the BBR team has installed a steel plate around the service openings to prevent punching.

6



To further strengthen the slab and prevent failure at the services aperture, carbon fiber-reinforced polymer (CFRP) is applied to the underside of the slab around the edge. This solution can also be used where there is less risk of deflection to the structure.

The team has doubled the amount of external PT for increased deflection control.

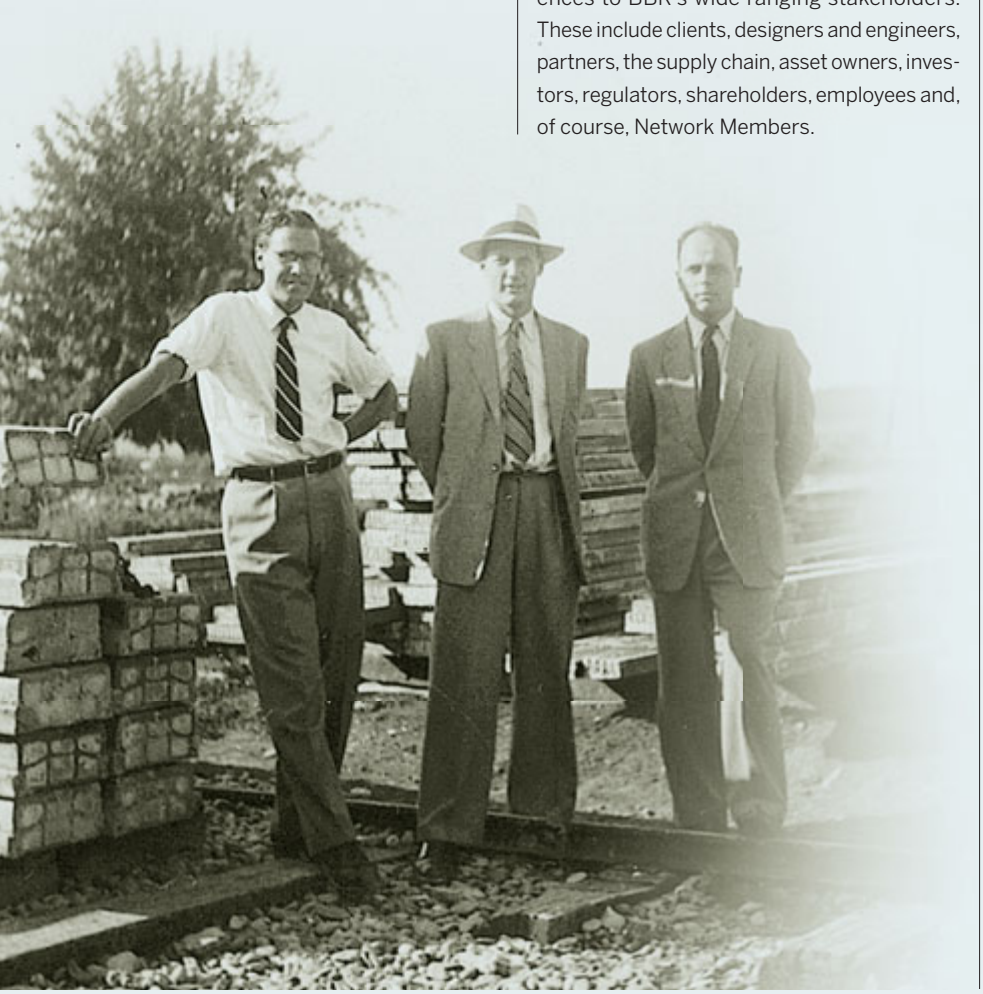
Doing more with less

80 years of enabling inspired design while reducing materials

The elegance and power of BBR's post-tensioning technology and know-how enables designers and engineers to create incredible and otherwise impossible structures. At the same time, they can employ less carbon intensive materials.

In this special edition of CONNÆCT, we are celebrating the many ways the BBR brand has remained relevant and successful for 80 years. What is the source of this longevity? Naturally, we keep returning to the underlying post-tensioning PT technology and know-how created in 1944 by the three founders (pictured below).

These three innovative and entrepreneurial engineers originally from industry and research—Max Birkenmaier, Antonio Brandestini and Mirko Roš—gave their names to the company, BBR (or Bureau BBR as it was known from 1945 until 1993). Their brand has since gone global, representing strong core values and delivering consistently positive experiences to BBR's wide ranging stakeholders. These include clients, designers and engineers, partners, the supply chain, asset owners, investors, regulators, shareholders, employees and, of course, Network Members.



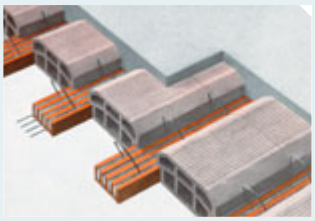
BBR's founders. Left to right: Antonio Brandestini (1915-2003), Mirko Roš (1912-68) and Max Birkenmaier (1915-2002).

Underpinning the brand, and what is at the heart of the business today, is its enabling technology and know-how. The original PT products, such as the Stahlton plank and BBRV anchor (pictured opposite), were born of a need to enable construction with less materials usage. It's the know-how of the people behind the technology, originally the three founders and, today, the expert scientists, designers, engineers and businesspeople in BBR VT and the Network, that has made the growing range of applications possible.

The products, solutions and know-how have grown and evolved but BBR's core enabling feature has not fundamentally changed in 80 years. As a result, BBR's range of PT solutions have not only lasted all this time but also evolved into some of the most versatile and powerful low-carbon construction technologies available. Being able to build with less material and, specifically, less cementitious material, means lower CO_2 emissions. Cable-stays and post-tensioned building slabs allow architects and engineers to design structures that would be difficult or impossible through traditional techniques. The bridges and buildings seen in the pages of this and past editions of CONNÆCT are evidence of just how versatile BBR's PT technologies and know-how can be. Reviewing nearly fifty years of marketing materials, some dating back to the early 1970s, shows many of today's core PT solutions to be remarkably like their forebears.

80 years on, BBR's PT technologies and know-how continue to adopt the very latest advances in digital engineering and science, widening the scope of what is possible. Industrial 3D printing also known as 'additive manufacturing,' was once the preserve of research and development for prototyping and low run complex components. These days, as you will read, entire structures are fabricated using 3D printers in a fraction of the time conventional processes require. Digital design and fabrication enable the production of structures that conventional engineering struggles, or finds impossible, to replicate—and with less materials.

This article captures some of the core qualities that make the BBR brand. We start with a trip to the archives (marketing shelves) examining how the technologies and know-how emerged into the solutions we recognize today. Then, we review some of the applications that particularly benefit from PT. Finally, we look to the future (another core element of the BBR brand) and explore digital technologies' contribution to our portfolio.



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1 BBR's first product, the Stahlton plank. A key component in high load bearing pre-fabricated slabs and lintels, this product inspired the Stahlton brand name.
2 The BBRV ground anchor was the first of BBR's geotechnical solutions. Alongside the Stahlton plank, the BBRV PT system with button headed wires, the know-how of Roš' design and engineering company, and Brandestini's Proceq, BBR's full offering was recognizable as early as the mid-1950s.
3 Built in 1961, the Schiller Steg bridge was the first cable-stayed bridge with BBRV anchors. It's still in use today.
4 Switzerland's Weinland Bridge over the river Thur—known to some as the Andelfingen Viaduct— was completed in 1958. This was the first time the BBR system had been applied to a long-span bridge project and the virgin application of 1,250kN capacity post-tensioning tendons.
5 Stahlton AG was founded in 1945 and has a fascinating archive of BBR marketing materials and memorabilia which Valentina Mihajlovic, BBR VT's MarCom & Events Coordinator, combed through. BBR VT's Zurich head office has a similar but smaller collection.
6 BBR's first nuclear power vessel was in 1965, although this brochure is from the early seventies.
7 Look at the Kinleith Mill story or the Khurais Hospital project on pages 76 and 82 of this magazine. There are clear similarities between the brochure images from the 1970s and the technologies today. But then the challenges are the same—strengthening and repairing buildings.

Enabling technology widens scope of applications

Searching the archives

To find out more about the growth of BBR's PT technologies, know-how and scope of applications, we explored BBR VT and Stahlton AG's archives for historic marketing materials. Still a thriving Swiss-headquartered design, engineering and manufacturing firm today, Stahlton AG was formed in 1945 in Frick to the west of Zurich. Mirko Roš was its President and remained so until his death. Max Birkenmaier took the Managing Director position, continuing until 1983. The company's archive has both archival video and technical and marketing materials. We felt privileged to view and scan these when researching this article. (You can read about Stahlton AG's latest projects on pages 52-57.)

However, no archival materials exist from before the 1970s so it is to the BBR 60th anniversary Innovative Engineering Review, coordinated by former BBR CEO and Chairman Dr Pietro Brenni (featured earlier in The Pioneers, pages 12-17), that we turn. This document reveals that Bureau BBR's first product was a pre-tensioned small beam, the Stahlton plank. These slabs were widely used in prefabricated slabs and lintels. Incorporating pre-tensioned steel wires and using burnt clay molds during fabrication, they were also the inspiration for the Stahlton AG brand name, 'Stahl, meaning steel and 'Ton' meaning clay in German.

From 1947 to 1949, the post-tensioning and anchoring approach as we know it today was perfected, leading to the BBR VT PT system with button headed wires. Sadly, there are no visual records of this product. Shortly after, the importance of the accompanying know-how was recognized as companies manufacturing BBR products under license realized they also needed the design and installation expertise. This led to Mirko Roš founding and engineering and design office in 1946. Antonio Brandestini, meanwhile, founded Proceq to provide equipment and expertise and it remains part of the Tectus Group. These steps took us closer towards the current BBR VT International of the 2020s, a hub of PT capabilities, expertise, experience and specialist equipment. In 1952, ground anchors were developed, beginning with the BBRV anchor, alongside tank and pipe winding solutions.

Applications

Having established a leading Swiss engineering firm offering PT construction solutions and supporting know-how, BBR rapidly starting winning larger projects and the scope of its applications widened. Following residential and leisure/retail buildings came industrial buildings, PT bridges, railway sleepers, large pipes (such as the Athens Aqueduct) cable-stayed bridges, foundations and earth-retaining structures, marine structures and, in 1965, nuclear reactor vessels. Over the next 20 years, more than 60 secondary containment vessels for nuclear reactors were built using BBR VT tendons. BBR's track record in critical engineering applications such as nuclear energy is strong, also extending to LNG/LPG and petrochemical tanks. These PT solutions all require further specialist qualities such as the ability to perform under extreme low temperatures.

BBR was also active in MRR although, during the 1970s, this phrase was not widely used; it did not appear until a 2002 brochure for that year's *fib* Congress held in Osaka, Japan. Another brochure from Stahlton AG's archives shows a page detailing strengthening and repair of structures. The brochure images from the 1970s are very similar to the pictures in the MRR section on pages 74 to 83 of this magazine, fifty years on.

BBR HiAm CONA anchors were developed in 1970, closely followed by the BBR VT CONA post-tensioning system with strands which was launched in 1972. By the early to mid-1970s, according to the brochures we retrieved and the history compiled in Pietro's BBR 60th anniversary Innovative Engineering Review, BBR's core product and solution portfolio nearly matched the modern range. Significant certifications included the 2005 European approved and CE marked BBR VT CONA range and, in 2016, a new generation of BBR VT CONA CMI/E electrically isolated tendons (EIT), enabling powerful corrosion protection.

Inspiration enabled

Even while using less materials and with less carbon emitted, BBR's core PT solutions have enabled engineers and architects to design some of the world's most iconic structures, underpin the world's transport and energy infrastructure, and delight society with inspiring spaces for leisure, work and sport.

Across these pages, we showcase some examples of the inspired design of iconic structures that were possible only because of BBR's enabling PT technology. Opposite, you can see how wind turbine towers benefit from more than one BBR PT solution.

No image can do justice to the Machinchang Bridge, located on Langkawi Island, Malaysia. Walkers can look down hundreds of meters to the jungle canopy itself 660m above sea level. The bridge's 2004 construction required a heavy lift helicopter since there is no access to the peak of the mountain Gunung Machinchang apart from via the Langkawi Skycab cable car. The walkway's location and unrestricted views, alongside the elegant simplicity, could not be created without BBR's cable-stays. BBR CONA Stay 706-1206, the forebears of the BBR VT CONA CMA system, were employed.

One of Europe's most recognizable structures, Munich's Olympic Stadium was built for the 1972 Summer Olympics and was the first to use newly launched BBR HiAm anchored strands to suspend the lightweight lattice-work tented roof. The BBR Network Member was Stahlton AG, supporting the designer Leonhardt, Andrä und Partner with their PT expertise. The stadium is still in use for local league football games.

Completed in 1997, the Tatara bridge linking the Japanese islands of Honshu and Shikoku is the longest cable-stayed bridge constructed in the 20th century. It has a main span of 891m and total length of 1,481m. Originally specified as a suspension bridge, the design changed to cable-stays so anchorage excavation would not be required. This would have caused local environmental damage.

Machinchang Bridge, Langkawi Island, Malaysia.

Olympic Stadium, Munich.

Tatara bridge, Japan.

As the size of wind turbine blades grow to optimize energy generation, so does the need for PT solutions.

The concrete tower element is stiffened using external PT, reducing the materials required, specifically concrete and cement, high carbon emitters.

The foundations are secured using ground anchors.

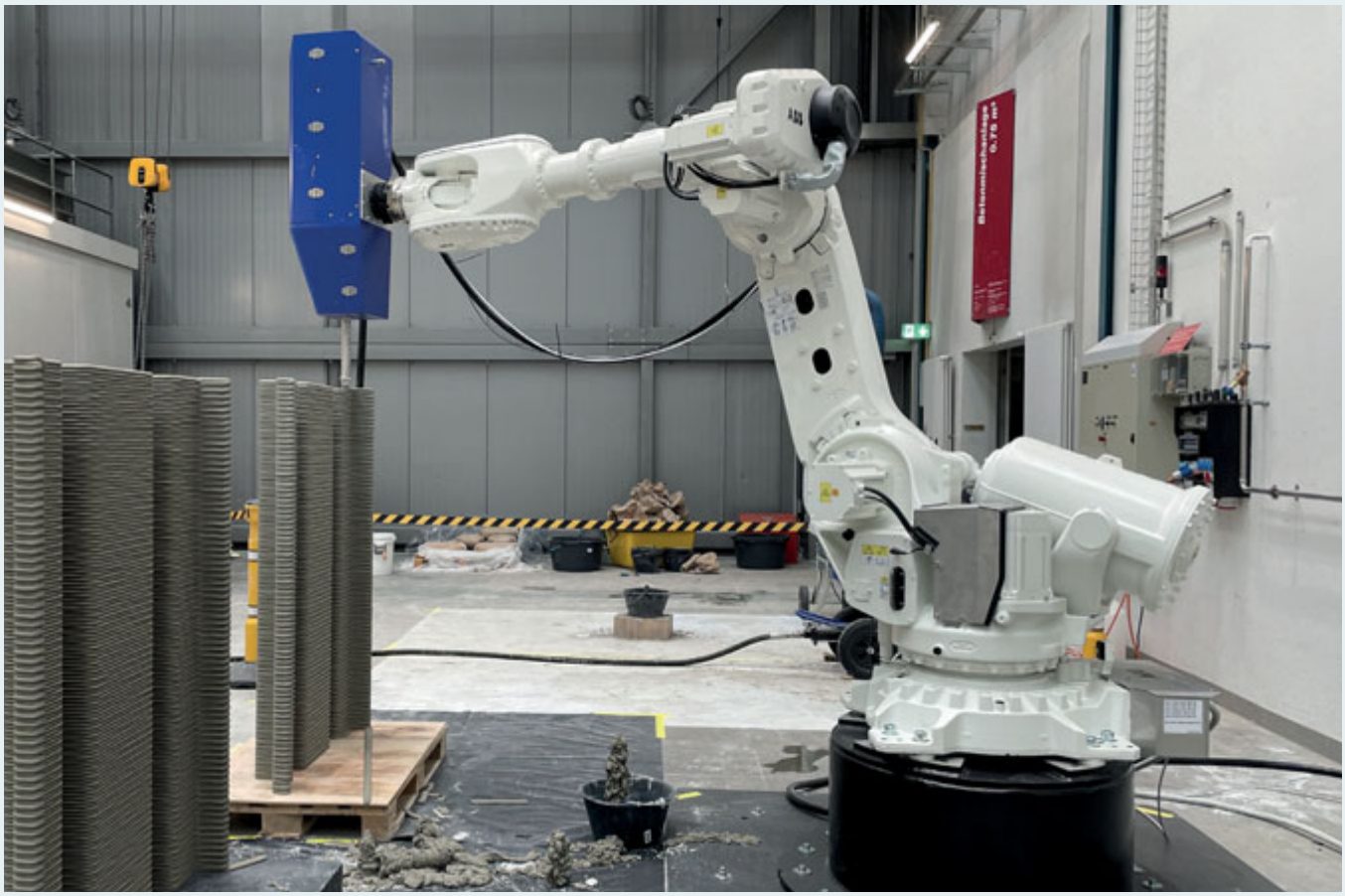
Energy enabled

During its 80 years of supporting energy infrastructure, BBR's PT technologies have enabled the design and construction of structures for nuclear reactors, LPG/LNG storage, wind turbine towers and offshore platforms. For wind turbine towers, PT provides multiple structural benefits.

Using low-carbon PT solutions is a force multiplier for renewable energy generation such as wind turbines. There are also several applications within the wind turbine tower that benefit from PT solutions. The towers used for onshore wind farms are typically composite structures with a concrete base and either a steel tower or a two-stage concrete and steel tower. Using PT technologies such as ground anchors for the base and external PT for the tower reduces the volume of material required for the tower and its foundations. It also increases the stiffness of the structure. This becomes increasingly important as the size of the turbine blades increases and height of towers grows, increasing stresses. Traditional approaches would require increased steel and concrete to accommodate the increased stress.

Two-stage turbine towers are enablers of greater and more efficient generative capacity. Larger blades turn more powerful turbines and advances in composite materials lighten blades, making larger blades possible—turning in a virtuous circle. However, the steel towers required to support much longer blades become uneconomical. Including a concrete base element to the tower increases height without necessarily increasing the steel tower. The size, reinforcement required and embodied construction carbon of the tower is reduced when external post tensioning is used.

PT provides further benefits for wind turbine towers. The foundations are secured using ground anchors. BBR's VT CONA CMG ground anchors can be specified for a service life of up to 100 years. This is far longer than most wind turbines with operating lives of up to 25-40 years. Now there are even more carbon saving possibilities because, if the underlying structure of the foundations and concrete tower outlast the turbines, the generative element of wind farms can be uprated as technology advances.



This 3D printer won't fit on your desk.

Digitally enabled

3D printing: the digital enabler

Multiple R&D programs are being coordinated by BBR VT International's Head of Technologies, Dr Haifeng Fan. These initiatives span new and evolved PT solutions. There are products to solve MRR challenges, exciting PT and materials advances in the nuclear field, and different digital solutions. One of these is 3D printing, which looks set to transform the built world.

Leading the digitalization program is BBR's Senior Project Leader Dr. -Ing. Xiaomeng Wang. He explains how BBR's 3D printing technology will carry the brand into its next 80 years.

Digitizing the built world, one slab at a time

Digitization in the built world is accelerating. One of the fastest growing areas is 3D printed concrete (3DPC). Employed alongside modular construction and PT, 3DPC has the potential to create new types of structure, introduce huge efficiency in time and materials, and carbon savings.

The nature of the production of 3DPC, the layer-by-layer extrusion, enables more creative and complex geometries compared to traditional concreting methods using wooden or steel formwork. The advance in cementitious materials and functional additives is continuously pushing the limits of printed concrete's compressive strength. However, the iterative manufacturing process, an advantage in so many other ways, becomes a barrier that prevents the introduction of ordinary reinforcement steel into the structure to provide additional tensile capacity for the printed concrete.

Many pioneers compromised with the low tensile strength issue of normal 3DPC and focus on applications of 3DPC in compression-type elements. In contrast, in partnership with the Swiss Federal Laboratories for Materials Science and Technology (EMPA) and ETH Zurich, BBR has proposed an alternative, distinct and reasonable approach to develop a system of 3D printed, post-tensioned slab (3DPPS). This approach optimizes the advantages of design

Left: Additive manufacturing is just the same as conventional precision manufacturing, creating components or modules exactly to specification and within tolerances. But these components can be of virtually any shape or size. One of the first volume applications was formwork, which can be used to create unique architectural features from concrete in a fraction of the time it would take for conventional formwork.

Right: Combining 3D printing with PT is a gamechanger. Initially, this takes the form of enabling rapid construction through formwork. Our research with EMPA and the ETH Zurich is designed to develop a novel floor slab system, 3DPPS, that offers materials reduction, design flexibility, automation and cost savings.

freedom by 3D printed stay-in-place formwork for slabs, while adding the combined benefit improving structural behavior and materials saving from post-tensioning technology.

3DPPS—why 3D Printed formwork with PT is a gamechanger

Conventional floor slabs are manufactured using standardized formwork, offering geometrically constrained shapes, very limited opportunities for automation, require a large labor force and are expensive to customize. Pre-cast prestressed slabs are more efficient than conventional ones, but the shape of such slabs is usually fixed and does not allow architects much freedom.

3D printing technology for post-tensioned slab systems is an optimal solution to address these issues. The system is made by the 3D printed concrete stay-in-place formwork, a dedicated post-tensioning system for 3DP materials, and a cast-in-place concrete topping. The architectural formwork, which may also be topologically optimized, can be manufactured offsite using 3D printing robots. Post-tensioning the formwork can further reduce the thickness of the formwork structure, increase load bearing capacity and improving crack resistance. The ultra-light prestressed formwork would be transported to the construction site and placed into the designed position. Finally, the concrete topping is poured.

The vision is to create a solution that delivers structural benefit with combined design flexibility and production efficiencies. PT adds structural performance and 3D printing offers design flexibility with automation. This sounds counter-intuitive, but 3D printed formwork can be standardized or unique to the project – there are no expensive molds manufactured for each design. Plus, automating the formwork production under factory conditions offers all the benefits of manufacturing best practice – quality, consistent production costs and control. Depending on the scale of the project, the slabs can be manufactured in modular manufacturing facilities onsite.

3DPPS is also doing more with less

3DPPS gives designers complete freedom to design real-world structures they could not through traditional approaches. Does this sound familiar? It's a lot like how PT has grown in applications; the efficiency of 3D printing enables engineers and architects to create a cutting-edge built world and using less material and emitting less carbon. The material efficiency is the highlight, with a potential savings of up to 80% on materials compared to the existing leading-edge formwork solutions on the market. There is an elegant alignment of 3DPPS with BBR's historic material and carbon reduction benefits.

The advantage of 3DPPS is beyond the technical level. Thinner, stiffer floor slabs mean reduced floor-to-floor heights, so more floors can be built within the same building height. This makes the structure more attractive to developers and their investors, as there are more floors and a greater amount of rent-generating floor area. The technology introduces a societal benefit, as in congested urban areas there is potentially more living, retail and hospitality, leisure and working area.

What could the future hold?

As we have seen in this technology article, the fundamental PT principles have not changed significantly since BBR was founded in 1944. Neither has the core set of products much altered since the 1970s. We've seen, though, how the solutions have evolved considerably with incremental innovation and improvements made year on year. Will the next 80 years follow this pattern? PT will remain at the core of BBR's future technologies. We're already experiencing how it will be joined by other revolutionary technologies, like 3D printing, to create novel solutions that solve many technical and societal challenges. Accelerating digitization, solutions like AI and genuine digital transformation will lead to future inventions. R&D at BBR means pushing the limits of what is possible and constantly moving away from our PT comfort zone.

How will our built world look in 2104..?

Our expanding global network
The UK and Ireland

Phoenix Specialist Contracting

Phoenix Specialist Contracting Ltd (PSC) is a UK-based firm with over 16 years of PT experience. This brings BBR technology to the UK and Republic of Ireland's multi-story building and civils projects and extends the BBR Network's presence in Europe.

Founded in 2008, PSC focuses on building slabs for residential, commercial, educational and hospital facilities and specializes in building, strengthening and renovation works for PT slabs and bridges. The team has worked on towers of up to 45 stories with 100,000m² slab areas. The company is independently owned and run by directors Derek Gedling and Alistair MacQuarrie, who have 40 years' PT knowledge gained both internationally and in their home market.

Of PSC's new partnership with BBR, Alistair said:

"The BBR Network seemed the perfect fit to develop our technical presence and credibility. We will be able to strengthen our presence in the UK and Ireland with a unique technical, partnering and resource approach. The BBR Network was a natural choice."

We look forward to seeing how PSC grows within BBR's Network and look forward to exchanging news and technical information with our new Members.

Derek Gedling and Alistair MacQuarrie
Joint Directors and Company Owners

James Bushi
Construction Manager UK

Bek MacQuarrie
Construction Manager Ireland

Alistair MacQuarrie details some of PSC's recent projects

Crown House, London. A 12- story office block, behind a retained Victorian façade. PSC reduced concrete quantity requirements, thinning the floor slabs with bonded flat slab tendons. The increased spans gave the owners greater flexibility and space.

For this balanced cantilever bridge carrying the A90 from Milltimber to Cookney in Scotland, the contractors chose a post-tensioned box girder. This minimized disruption (formwork or piling) to the protected salmon stream in the River Dee flowing below.

This mixed-use development at First Street in the city of Manchester involved the design and construction of bonded PT floor slabs for three, slip-formed core towers of between 22 and 45 stories. This reduced cycle times, floor-to-floor, and brought down slab thickness and passive reinforcement. We achieved significant programme savings in the frame construction and ensured minimal environmental impact.

Our expanding global network
The Netherlands and Belgium

De Vries VSP

De Vries VSP b.v, part of the Vrieshold Werkendam b.v.Group and headquartered in Werkendam, has delivered PT solutions for more than 20 years to customers in infrastructure, transport, utilities and industrial, as well as to contractors. De Vries VSP's BBR Network membership means customers in the Netherlands and Belgium can benefit from the full range of BBR's PT solutions. The team's expertise spans road and rail bridges, cable-stay bridges, buildings, marine geotechnical, tanks, special projects and MRR. A key feature of the company's offering is its design capabilities. As a result, the team is often involved in projects at an early stage so the full benefits of choosing a PT solution can be applied. The PT company was launched in 2002 by director Jan Luijten, who says:

"We plan to introduce BBR's technologies in two ways. Where new build and special projects will benefit from BBR's PT solutions, like the BBR HiAm CONA range for cable-stay bridges and introducing the ETA-certified BBR VT CONA CMG ground anchors to the Dutch market."

"MRR is also an opportunity for our expertise, especially on cable-stay bridges that feature BBR's technology which needs to be renewed after over 50 years. Our plan is also to grow our geographical coverage wherever possible."

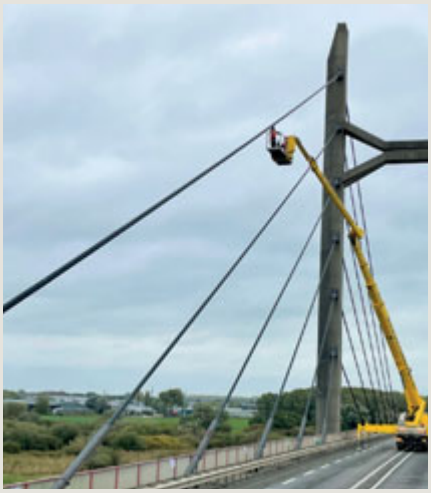
The group includes a further three brands that bring additional expertise: De Vries Werkendam, De Vries Titan and Immontec.

The De Vries team welcomed at BBR VT International's headquarters in Zurich. Left to right: Paul Posthoorn (Business Unit Manager), Dammes Oldenburg (Director), Olivier Forget (BBR CEO) and Jan Luijten (Director).

More of the De Vries team at the Werkendam office. Left to right: Paul Posthoorn (Business Unit Manager), Arjan Stehouwer (Project Leader) and Nihm Makkinga (Site Engineer).

Paul Posthoorn details one of De Vries' recent PT projects

The Molenbrug Bridge over the River Ijssel is a vital link between the towns of Kampen and IJsselmuiden, 100km east of Amsterdam, in the Netherlands. The Rijkswaterstaat (Ministry of Infrastructure and Water Management) commissioned De Vries VSP to inspect the BBR system cable-stays.



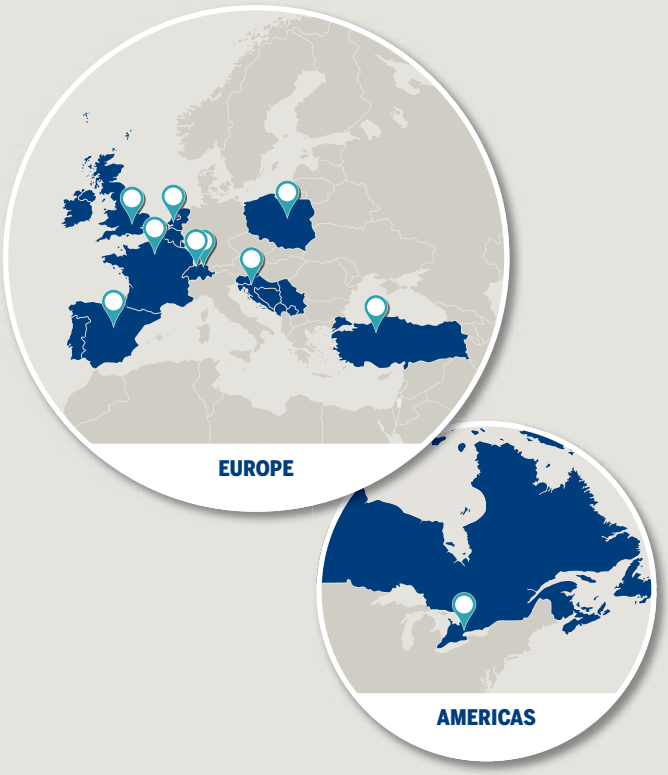
The bridge was built in 1983 and was last inspected in 2014. During October 2022, the De Vries VSL team inspected the 48 BBR HiAm CONA stay cables, which showed that the bridge has deteriorated, and the team advised on how to preserve the corroded steel.

The bridge will require further investigation, as the initial inspection showed corrosion in two locations at the forks' anchor points.

Our global presence

Our clients are based in over 50 countries – so our global presence is a vital asset.

We can share our international experience locally, provide solutions adapted to specific conditions and be on hand to offer a personalized service.



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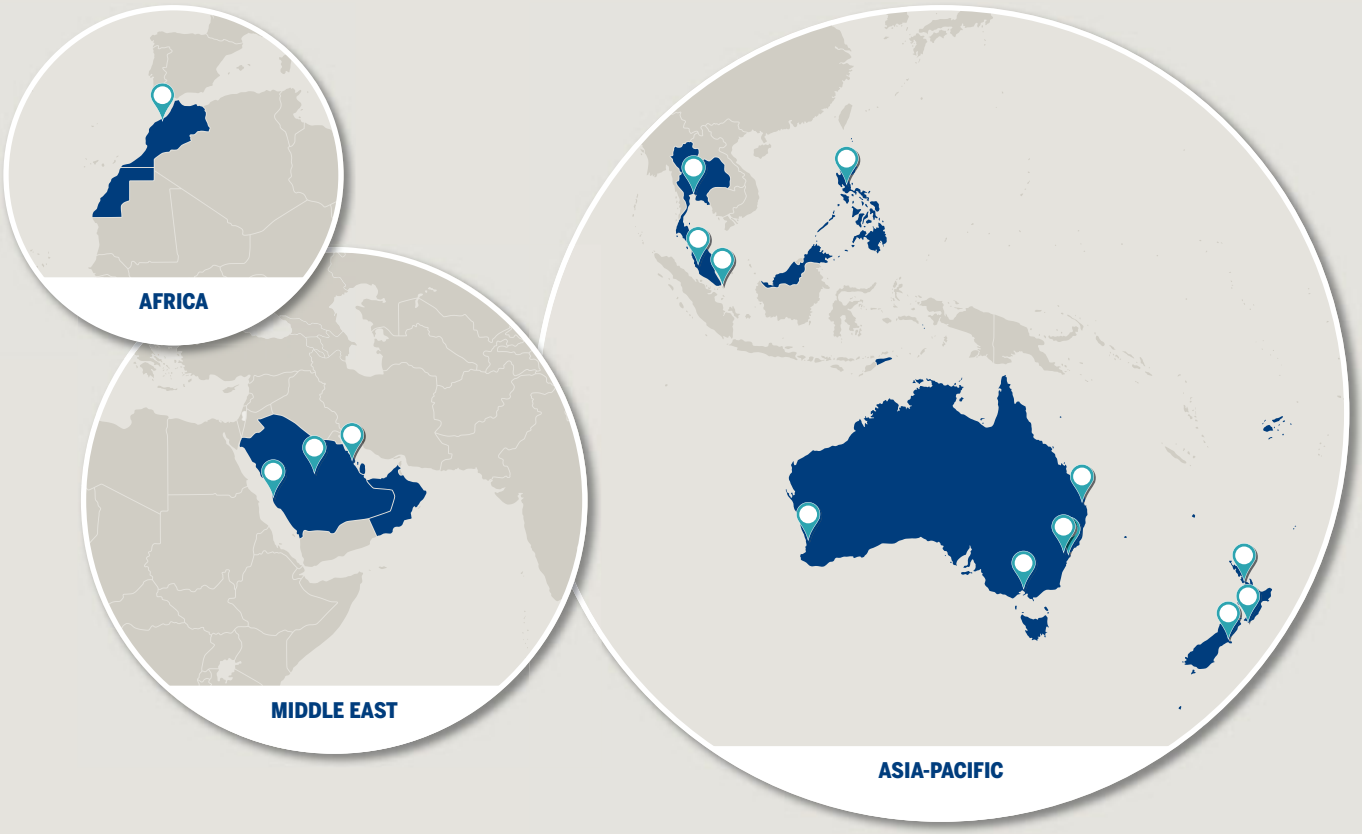

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