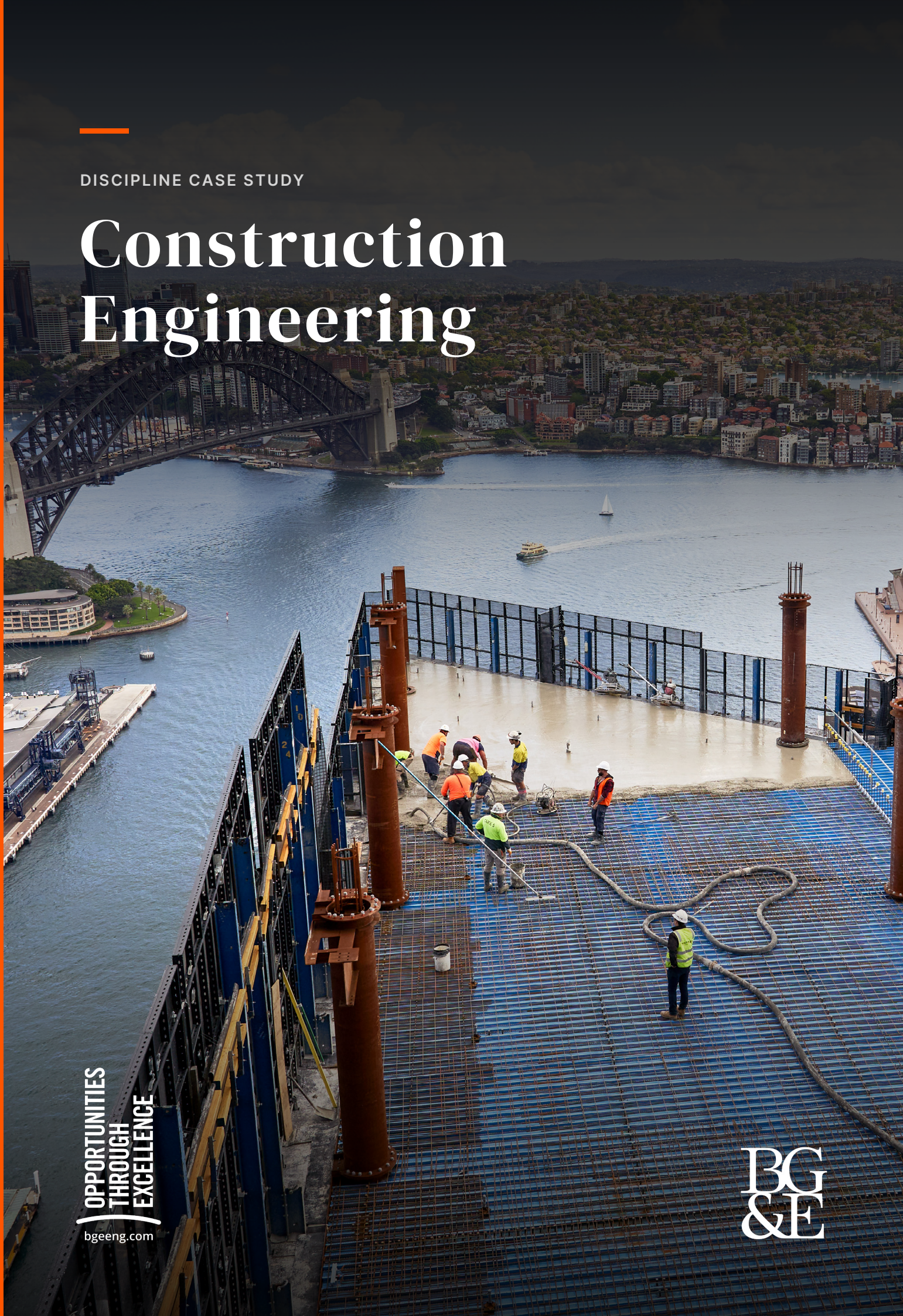
DISCIPLINE CASE STUDY

Construction Engineering



OPPORTUNITIES THROUGH EXCELLENCE

bgeeng.com

BG&E

Sydney Metro City & Southwest (SMCSW)

SYDNEY, NSW, AUSTRALIA
CLIENT: JOHN HOLLAND, CPB CONTRACTORS & GHELLA JOINT VENTURE

The Sydney Metro City and Southwest (SMCSW) project will extend the metro rail between Chatswood and Marrickville and will include a new tunnel beneath Sydney Harbour.

Arcadis and BG&E in a joint venture (ABJV) were engaged to do the tunnel station excavations, surface civil works and selected permanent and temporary works structures. In addition to the original scope of work, the BG&E team of engineers have provided construction engineering assistance and temporary work design.

The SMCSW is a 15.5 kilometre project, spanning from Chatswood to the Marrickville area, including a crossing beneath Sydney Harbour. The project includes:

- Constructing running tunnels with waterproofing using tunnel boring machines (TBMs) for dry tunnels, mined cross passages, a cavern for a rail crossover at Barangaroo, tunnelling below Central Station, and creating mined station caverns with adits for new stations at Victoria Cross, Martin Place, and Pitt Street, including a connection to the existing Martin Place Station on the Sydney Trains Eastern Suburbs Line.
- Demolition, excavation, and concrete structures for dives in Chatswood and Marrickville, as well as for new stations in Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street, and Waterloo.

- Installing a permanent concrete lining in all tunnels, caverns, adits, cross passages, and underground openings to accommodate future track bed and rail and station services.
- It also includes constructing the primary concrete structure at the new Barangaroo station and ensuring safe personnel access to underground spaces with temporary support services, including maintaining site facilities for handover to Follow-on Contractors upon completion.
- Removal of all temporary work and site facilities not otherwise required for handover to Follow-on Contractors.

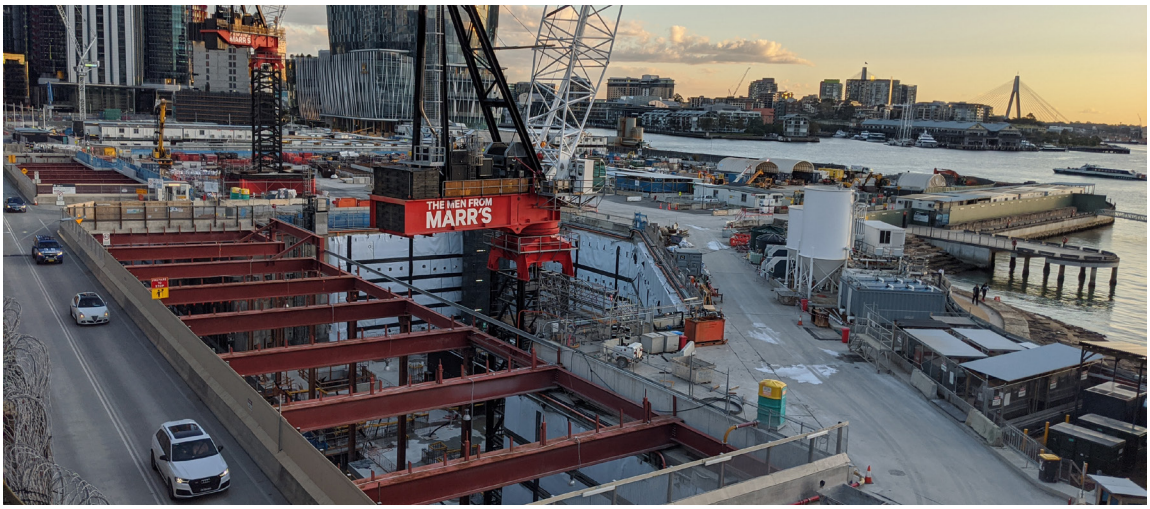
Sydney Metro City and Southwest - Sydney, NSW, Australia.

BG&E and Arcadis Jointed Venture were responsible for following scope of works for the TSE design:

- Design of temporary and permanent civil works (roadworks, drainage, temporary and permanent storm water diversion, flood modelling, utility coordination, road safety audit, traffic modelling, traffic staging, temporary works etc.).
- Design of temporary and permanent structures for all open box, shaft and dive sites (bored and CFA piling, shoring, steel platforms, deep excavation over 40m, drained and undrained structures, etc.).
- Building effects assessment.
- Project wide durability assessment.
- Earthing and Electrolysis assessment.
- Project wide flooding assessment.
- Project wide CAD and BIM management.

Barangaroo Station & Hickson Temporary Road Bridge

SYDNEY, NSW, AUSTRALIA
CLIENT: JOHN HOLLAND, CPB CONTRACTORS & GHELLA JOINT VENTURE



As part of the $2.8 billion Sydney Metro City and Southwestern (SMCS) Tunnels and Station Excavation Works contract (TSE), BG&E was appointed by JHCPBGJV to undertake the detailed design of the Barangaroo station excavation and Hickson temporary road bridge.

Following this, BG&E were appointed by JHCPBGJV to design the stations' permanent structure.

BG&E's third contract on the project was awarded by Besix Watpac - providing temporary works and construction advice during the commissioning and fitout of the station and construction of the permanent surface works and roads.

Project Details
The station excavation is typically rectangular in plan with proposed bulk excavation level to be at approximately RL – 24.5 metres.

Barangaroo Station Excavation and Hickson Temporary Road Bridge – Sydney, NSW, Australia.

The retention system is comprised of soldier pile walls, with the inclusion of jet grouting between piles, and anchors for the western retaining wall and headwalls. A shotcrete face will be constructed in front of the soldier piles.

The shotcrete wall is connected to the piles with dowels. The intent of the soldier piled solution is to provide a tanked solution for the structure sitting above the sandstone bedrock. A blinding layer will be provided at the base of the excavation, with a longitudinal fall to facilitate drainage.

Temporary acoustic roof and steel bridge structure for public access were provided to allow for the station excavation and construction activities to continue. To maintain public access to the Station along Hickson Road heritage retaining wall, two lane suspended public access bridge was built over the full length of the box excavation. The public access bridge was supported on temporary piles and steel girders traversing the excavation.

At later stage, the temporary bridge steel girders were extended to provide a construction access alongside the western retaining wall and 2 future bridges crossings over the excavation also required for construction access.

In the scope for Besix Watpac, the temporary bridge had to be partially demolished while the new road over the station was built, with the road then being rediverted to be supported over the station box.

Quay Quarter Tower

SYDNEY, NSW, AUSTRALIA
CLIENT: AMP CAPITAL

BG&E provided structural and construction engineering services (including permanent and temporary works) and materials testing services (including highly complex modelling and analysis) to Quay Quarter Tower (QQT) - a highly sustainable commercial vertical village that is recognised as the largest adaptive reuse project in the world.

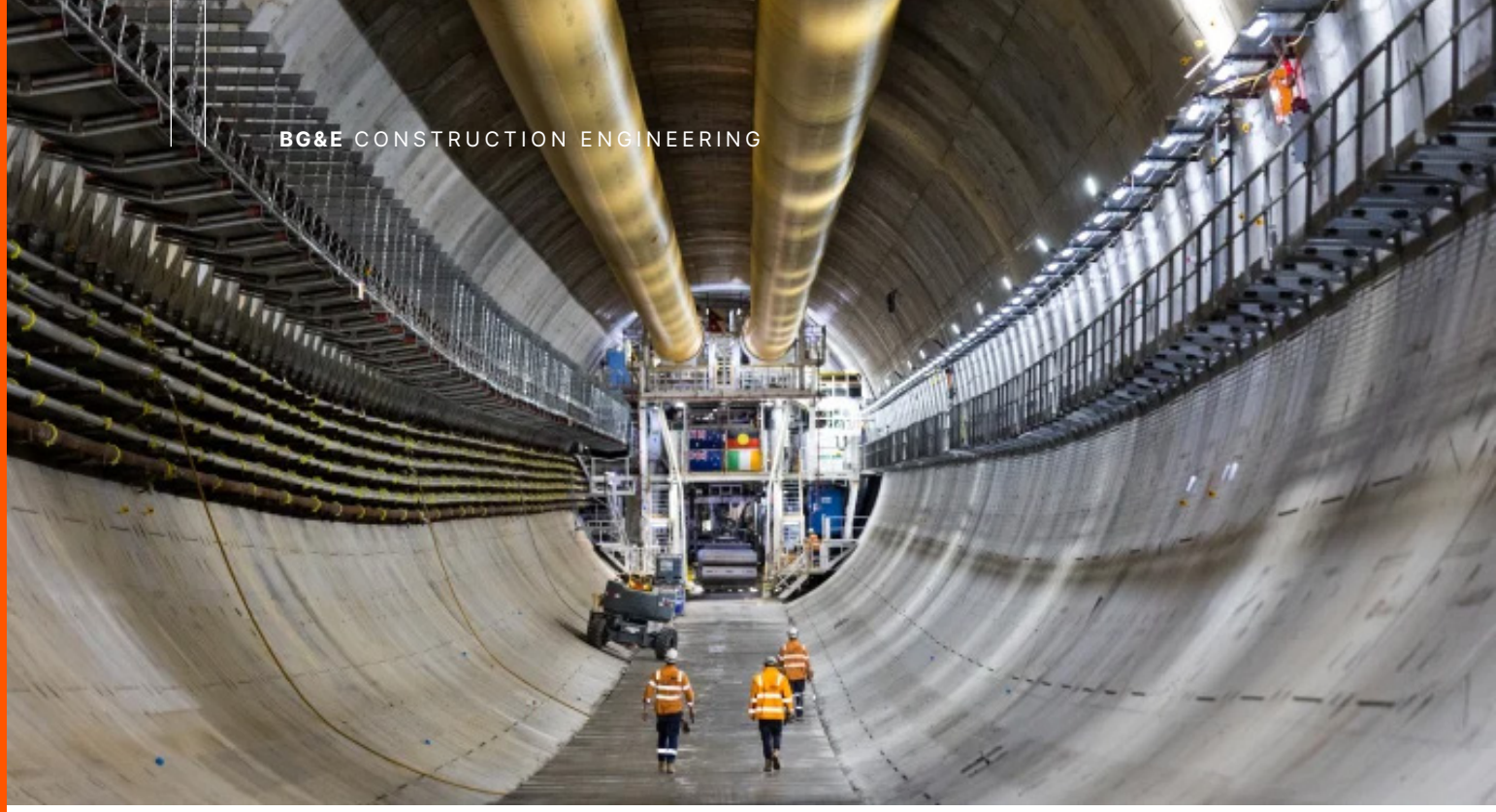
In a construction world-first, one side of the tower was demolished and reconstructed, while the other side of the tower was retained and refurbished simultaneously – enabling significant environmental and operational efficiencies.

During the upcycle of the existing building, around two-thirds of the towers original core were retained – conserving approximately 12,000 tonnes of embodied carbon.

The upcycled QQT now boasts doubled usable area and user accommodations, compared to the original tower – from 45,000 sqm to 102,000 sqm of usable area, and from 2,500 to 9,000 user accommodations, respectively.

The global recognition bestowed upon QQT is a testament to its remarkable achievement. It was awarded the 'World Building of the Year' at the 2022 World Architecture Festival (WAF) in Lisbon and received the prestigious 2022/23 International High-Rise Award. These accolades highlight the extraordinary transformation and sustainability of the project, setting a new global standard in adaptive reuse.

The upcycle of the existing AMP centre tower into QQT has set a new global standard in adaptive reuse, bearing testament to an ambitious team, innovative design, and technical engineering excellence – with the result being a saving of over 12,000 tonnes of embodied carbon when compared to the traditional demolish and rebuild route.



Western Harbour Tunnel

SYDNEY, NSW, AUSTRALIA
CLIENT: ACCIONA

The Western Harbour Tunnel is a major transport infrastructure project that will make it easier, faster and safer to get around Sydney.

Extending from the Rozelle Interchange to the Warringah Freeway, the creation of a western bypass of the Sydney CBD will take pressure off the Sydney Harbour Bridge, Sydney Harbour Tunnel, Anzac Bridge and Western Distributor corridors to improve transport capacity in and around Sydney Harbour.

BG&E was engaged by Acciona to provide structural, civil, geotechnical, construction engineering (temporary works), facade and waterproofing design services across three different sites in Sydney - Cammeray, Rozelle and Berrys Bay.

Key aspects of the design services provided by BG&E include:

- Temporary works design including civil and pavement design to facilitate site establishment, structural steel site shed design, gantry crane design and other miscellaneous temporary works.
- Four gate design process, similar to other major TfNSW infrastructure projects (DCD, SDD, FDD, IFC).
- Frequent interfacing workshops with other disciplines including Architecture, Tunnels, Monitoring and Evaluation (M&E), Fire Engineering, Durability and Construction.

- 100-year design life for all permanent concrete structures (including fixings) and any elements unable to be replaced or maintained.
- Design of partially suspended RC slabs supporting large water deluge tanks above a decommissioned underground decline structure.
- Extensive Architectural and M&E coordination for the Cammeray site to enable construction and tunnel commissioning at the Interim and Ultimate phases.
- Spaceproofing and excavation coordination interface with below-ground ventilation tunnels and adjacent infrastructure assets at Cammeray.
- Design of the ventilation outlet in a restricted triangular site allowing for construction with live traffic on the Warringah Freeway.
- Bespoke assessment of elements to be demolished and modified to existing Rozelle interchange maintenance buildings.
- Consideration of M&E space, loading and fire resistance requirements for permanent fit out structures in the existing Rozelle tunnel network.
- Reviewing documentation of Rozelle and Southern Tunnel packages to assess the impact of WHT works on existing structures.
- Given the space constraints at the Cammeray site, along with the complexities of underground tunnels and multi-discipline interfaces, careful consideration was required for construction staging and coordination with the tunnel and WFU design elements.

Western Harbour Tunnel – Sydney, NSW, Australia.

Sydney Metro West - Eastern Tunnelling Package

SYDNEY, NSW, AUSTRALIA
CLIENT: JOHN HOLLAND, CPB CONTRACTORS & GHELLA JV

The Sydney Metro West project is a new 24 kilometre underground metro railway that will double rail capacity between Parramatta and the Sydney CBD, transforming Sydney for generations to come.

John Holland CPB Contractors Ghella Joint Venture (JCG) has been awarded the contract to design and build the tunnels for the Sydney Metro West – Eastern Tunnelling Package (ETP).

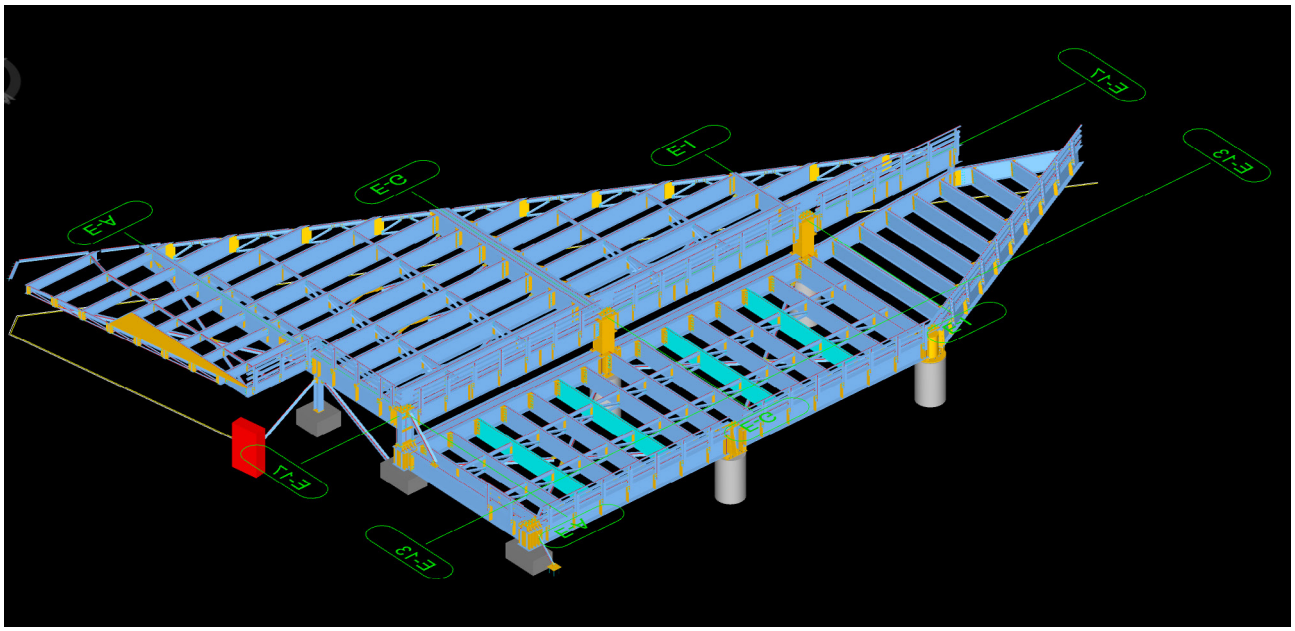
The ETP works include the construction of 3.5 kilometre tunnels under Sydney Harbour between The Bays and Sydney CBD and the excavation of Pyrmont and Hunter Street stations.

Starting at The Bays, tunnel boring machines will cross the harbour near the Anzac Bridge, before heading to the new Pyrmont Station and then under Darling Harbour before reaching Hunter Street Station in the heart of the CBD.

This once-in-a-century infrastructure investment is Australia's biggest public transport project and will provide fast, reliable, turn-up-and-go metro services with fully accessible stations, link new communities to rail services and support employment growth and housing supply.

BG&E, in joint venture with Arcadis, was engaged by JCG to provide structural, civil, geotechnical, temporary works and construction phase services associated with the station excavations works and enabling works for the TBM operations.

This included design of steel working platforms over the station excavation at both Pyrmont and Hunter Street along with complex construction and demolition staging design adjacent to existing heritage buildings. The design of temporary structures to facilitate TBM launching at The Bays, such as segment and spoil shed structures, grout and water treatment plant structures and significant temporary civil works to facilitate construction activities.



Pyrmont Site Temporary Platform Model
Eastern Tunnelling Package – Sydney, NSW, Australia.

Sydney Football Stadium

SYDNEY, NSW, AUSTRALIA
CLIENT: JOHN HOLLAND

The Sydney Football Stadium (SFS), now known as Allianz Stadium, is a $828 million, state-of-the-art stadium near Sydney's CBD that was funded by the NSW Government and reopened to the public in 2022.

BG&E was engaged to undertake temporary works for the fabrication, transportation, and erection of the steel roof for SFS. These works included:

- Erection staging of the major roof elements, including a staged FEA model for each roof element, with temporary supports on the pitch to control the local soil bearing and overturning.
- Review of lift studies and design of temporary supports for out-of-plane lifting induced loading.
- Design of the temporary support jigs and mechanisms to allow movement in the stressing stages and lifting of the radial arches.

The new stadium was built to meet the future safety and access requirements and boost growth in the Sydney visitor economy.

Fortitude Valley School

BRISBANE, QLD, AUSTRALIA
CLIENT: QUEENSLAND DEPARTMENT OF EDUCATION

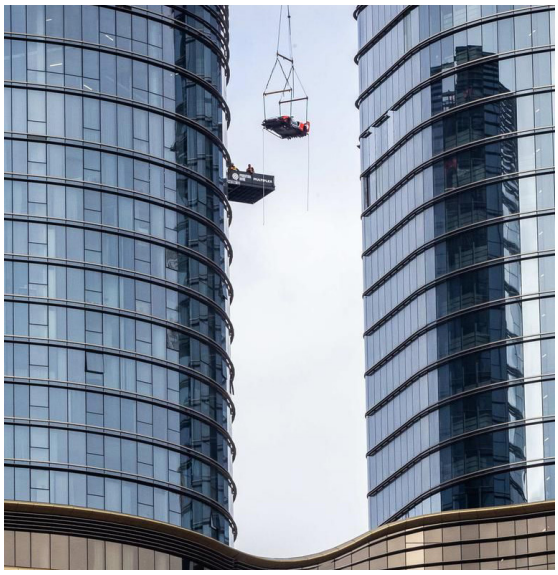
BG&E provided construction engineering services for the sports centre of the College, which was a part of the $98.7 million redevelopment.

Fortitude Valley State Secondary College is the first school to be opened in the inner-city Brisbane in over 50 years. The redevelopment included the following elements:

- Structural features, which included 23 metre concrete floors spanning over twin basketball courts.
- Due to proximity to the rail line, the design takes into consideration rail impact loads and partial collapse criteria.
- A fully precast structure. Our scope of services encompassed the erection sequencing of the precast elements to assess their strength during each of the stages of construction. The team also designed all temporary works to provide stability and maintain integrity of the precast.
- We provided 4D rendered animations and staging for the erection and removal of the temporary props to assist the builder with communicating the construction sequence with the trades on site.

Sapphire by the Gardens

MELBOURNE, VIC, AUSTRALIA
CLIENT: MULTIPLEX



BG&E were engaged by builder Multiplex, to provide construction engineering and temporary works services to Sapphire by the Gardens, a development which comprises two concrete towers - a 59-storey hotel named Shangri-La by the Gardens, and a 57-storey residential tower called Sapphire by the Gardens. Notably, these luxury towers are interconnected by an innovative sky bridge located on the 46th floor.

We provided a full range of construction engineering and temporary works services to the residential / hotel development – including tower cranes, temporary propping, shoring of Alimak, man and materials hoists, and construction logistics at roof level.

A noteworthy side project that stemmed from the development was the crane lift of a $3 million McLaren supercar to its new home in the 54th-floor penthouse of Sapphire by the Gardens.

BG&E were asked to conduct a peer review and proof engineer for the proposed crane lift of the supercar - a delicate operation that involved meticulous review of the car's rigging arrangement to ensure a secure and level operation. Upon assessing the proposal, our team identified that the clearance under the McLaren was only 60 millimetres, prompting us to propose crucial modifications to facilitate the successful crane lift of the McLaren.

Level Crossing Removal Project

MELBOURNE, VIC, AUSTRALIA
CLIENT: JOHN HOLLAND

The Level Crossing Removal Project is a key initiative of Victoria's Big Build that aims to eliminate 110 dangerous and congested level crossings in Melbourne by 2030, marking the largest endeavour of its kind in the state's history.

BG&E played a vital role in the North Western Program Alliance, Victoria, contributing to multiple project sites including the Bell Moreland Level Crossing Removal Project, the Bell Preston Level Crossing Removal Project, and the Keon Park Level Crossing Removal Project. Our team were integral to the temporary works division and provided services relating to assessing girder installation stability and lifting for the precast U trough segments.

The removal of level crossings not only enhances safety for road users and pedestrians, but also reduces congestion, making travel more convenient for those who use public transport, walk, cycle, or drive, while simultaneously generating thousands of job opportunities during construction and enabling people to get home more safely and quickly.

Melbourne Metro

MELBOURNE, VIC, AUSTRALIA
CLIENT: CROSS YARRA PARTNERSHIP

The Melbourne Metro project stands as a pivotal transformation for the city of Melbourne, encompassing a nine-kilometre tunnel beneath the central business district (CBD) to connect the West and East, with an estimated cost of approximately $11 billion.

The Metro not only serves as an economic stimulus but also contributes significantly to employment opportunities in the vibrant capital of Victoria. Upon its completion, Melbourne Metro will bring about a substantial enhancement in commuter capacity and trip frequency.

As of October 2023, BG&E has successfully delivered close to 200 packages of work, including temporary works design and a range of other services. The major phases of this project were completed in 2022, marking a significant milestone in our commitment to contributing to the success of the Melbourne Metro.

Melbourne Metro – Town Hall Station

MELBOURNE, VIC, AUSTRALIA
CLIENT: CROSS YARRA PARTNERSHIP

BG&E has been responsible for designing and documenting numerous significant packages of work to enable the excavation and construction of the Town Hall Station. We have undertaken works at all three of the access shaft sites, inside the station cavern and as part of the works to tie into Flinders Street Station.

Work packages included:

- Assessment of the existing Federation Square structure for the temporary construction arrangement, including demolition of significant lateral stability elements and replacement with temporary propping, to enable construction of an access shaft into the station cavern. BG&E also undertook construction staging analysis to optimise the build out of the main Federation Square shaft in conjunction with the adjacent secondary shaft, which will hold the escalators.
- Temporary retention walls and strutting of a 40 metre long and 5.6 metre wide trench in the roadway of Flinders Street, which was required for the construction of a permanent reinforced concrete pedestrian tunnel linking the station cavern with Flinders Street Station. Maintaining these temporary supports throughout various stages of the construction process through coordination with other stakeholders and careful staged construction sequencing.

Melbourne Metro Flinders Link - Dive Structure - Melbourne, VIC, Australia.

- Two tower crane gantries sitting over the public footpath on Swanston Street to enable removal of the temporary shed and heavy deck at the City Square shaft and construction of the permanent structure. Crane foundations were constrained on one side by the station works and on the other by numerous services running below the footpath and roadway, requiring close coordination with the construction team, Melbourne City Council and the asset owners.
- A large platform spanning over the City Square access shaft, which supported ventilation and scrubber units to ensure clean, fresh air for the teams working in the tunnel. Space constraints from the shaft retention system resulted in the deck having a unique doubly hung arrangement, with the primary beams hanging down from the capping beam on each side of the shaft and the secondary beams hanging from the primaries. This arrangement required exploration of custom sections and connection detailing with the Client and steel shop detailer, along with construction and demolition sequencing.
- Construction staging analysis of the top-down construction at the Flinders Over Site Development (OSD) site to fast-track completion of the substation to allow trains to start running through the tunnel for testing – a key milestone for the project. The assessment also optimised the sequence for removal of the temporary plunge columns, which supported the upper floors of the station until the columns and liner wall had been completed.

- Temporary shafts in each of the platforms of Flinders Street station to access construction of lift shafts running from platform level to the underpass below. These works have ensured DDA access between the platforms of Town Hall and Flinders Street Stations. Each shaft was tightly constrained by the heritage-listed platform structures, which remained operational throughout, and were further complicated by highly adverse ground conditions.
- Construction sequencing and loading assessments of each concourse slab within the station cavern at both Town Hall and State Library Stations to avoid temporary propping of these slabs, allowing train testing to start while construction continued. The construction team's requirements for these slabs were highly dynamic, but BG&E's responsive and engaged team ensured the construction programme remained on track.

Melbourne Metro Federation Square - Temporary Works - Melbourne, VIC, Australia.

Melbourne Metro – State Library Station

MELBOURNE, VIC, AUSTRALIA
CLIENT: CROSS YARRA PARTNERSHIP

Construction of the new State Library Station was highly complex, with five separate access shafts, along with the station cavern sitting under Swanston Street.

Construction sequencing between the main rail tunnel and adjacent station box was such that the tunnel boring machines for the main tunnels would pass the station box prior to its construction.

For safety reasons, a connecting adit between the tunnels and station box needed to be complete prior to the TBM's passage. To enable construction of the adit, a 26 metre deep 'D' shaped temporary shaft was constructed. The temporary shaft, designed by BG&E, has been constructed using concrete soldier piles, shotcrete infill panels, with a top capping beam and intermediate ring beams to provide lateral support to the piles.

Control of settlement and ground movement was a key design constraint to protect adjacent tall buildings and other surrounding infrastructure. Strain gauges and other monitoring devices were installed to provide real time feedback of actual movements with alarm states activated if detected movements exceeded predicted movements. Once the adit was completed, the shaft was backfilled and then progressively demolished as the permanent shaft, within which it sits, was excavated.

Other Melbourne Metro Sites

MELBOURNE, VIC, AUSTRALIA
CLIENT: CROSS YARRA PARTNERSHIP

BG&E's participation in the Melbourne Metro Temporary Works project extended to all the Metro sites, including:

- Steel bumper beams at Arden Station to prevent impact being precast concrete arch pieces and the adjacent completed structure during arch installation.
- Brackets to support the large, temporary steel struts and walers retaining the walls of various shafts, including at Parkville. BG&E's proposed connection details incorporated allowances for construction tolerances - such as piles installed out of position and allowing these brackets to be fixed to the shotcrete wall instead of the piles, to avoid clashing with heavy reinforcement within the piles.
- Polymer fibre reinforced shotcrete infill walls spanning between the shaft piles, where the rock was good quality to remove the requirement for steel mesh reinforcement, allowing faster excavation.
- Steel-framed concrete hoppers and concrete pipe restraints at Anzac Station and the Eastern Portal sites, to allow improved delivery of concrete from street level to the base of the shafts.

North East Link

MELBOURNE, VIC, AUSTRALIA
CLIENT: SPARK CONSORTIA

The North East Link represents a significant investment in Melbourne's north-east, aiming to transform transportation in the city.

BG&E were engaged to design four crane pile caps and piles at two different sites, Lower Plenty Road and Manningham.

Slated to be completed in 2028, The project includes the construction of tunnels to address a crucial freeway network gap, removing 15,000 trucks from local roads daily and reducing travel times by up to 35 minutes. Additionally, it will involve the completion of the Ring Road in Greensborough, a revamp of the Eastern Freeway, the establishment of Melbourne's first dedicated busway, and the creation of the North East Trail, offering over 34km of pedestrian and cycling paths.

Optus Stadium

PERTH, WA, AUSTRALIA
CLIENT: BROOKFIELD MULTIPLEX

BG&E provided civil and structural engineering services for Optus Stadium, Australia's third largest stadium.

Formerly New Perth Stadium, Optus Stadium was completed in 2018 and accommodates up to 60,000 patrons, with potential expansion of up to 70,000 seats.

Our civil engineering team:

- Improved the 73-hectare precinct's land conditions to minimise ongoing maintenance for pavements, roads, in-ground services, and key landscaped areas.
- Considered interfaces with surrounding transport infrastructure, resulting in an integrated design for civil and landscaping works.
- Overcame challenging ground conditions and settlements by suspending all ground slabs on piled foundations, integrating services into the slab using thickenings and service trenches.

Components of the structural engineering include:

- The stadium's superstructure features a steel frame with overall stability achieved through reinforced concrete walls designed to align with the stadium's layout and accommodate lift shafts, service core, and plant rooms spanning the building's height.
- The suspended slabs from level one to level five have been designed as conventional reinforced concrete slabs cast on Bondek to eliminate the need for propping during construction.
- The seating plats are precast prestressed concrete elements spanning a double grid of around 12 metres. The seating elements are generally single elements to simplify the pre-casting process and to limit the weight for lifting during installation.
- The structural roof is a three-dimensional triangulated steel truss cantilever with a small back span to minimise the roof envelope. Fabric has been installed to the underside of the trusses which provides a triangulated open truss to the top. This roof structure was chosen to satisfy the Client's requirement for a roof system that was prop-free and modulated.

Optus Stadium - Perth, WA, Australia.

Opus Building

DUBAI, UAE
CLIENT: BROOKFIELD MULTIPLEX

BG&E provided structural engineering services to the Opus, a mirrored glass building that consists of two 21-storey towers connected at roof level by a six-storey deep composite sky bridge and six basement levels, designed by the late architectural legend - Dame Zaha Hadid.

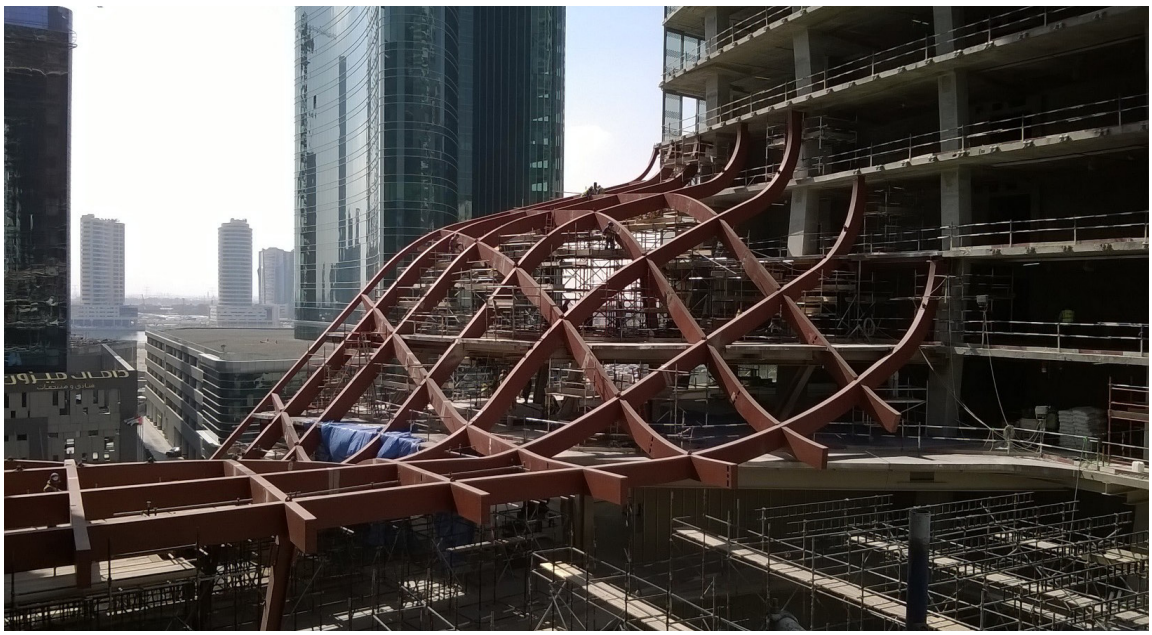
Due to the unusual shape of the building, an innovative construction methodology was developed for the bridge assembly, podium, and temporary platform on the underside of the bridge that enabled facade installation.

The groundbreaking segmental construction sequence for the bridge involved building main trusses and external facade grids bottom-up.

Upon releasing temporary diagonal members, load paths transitioned from temporary to permanent, forming a ‘top-hung’ structure. This innovative approach enabled simultaneous work in various locations across the site, allowed the use of lower-capacity cranes, reduced steel segment tonnage, and minimised construction time and overall construction cost.

Other innovative design outcomes achieved by BG&E include:

- Saved 3 months in construction time by revising the footing design and removing 240 piles from beneath the tower footprints.
- Incorporated an isolation strip in the hydrostatic slab to prevent differential settlement stress, reducing reinforcement needs by 30% at the junction between the hydrostatic slab and raft and saving over 60 tonnes
- Designing flat floor slabs that eliminated the need for edge and cross beams, improving constructability and reducing program time. Podium and link bridge complexities were removed from the critical path by shifting to composite steel construction. Opening three simultaneous construction fronts expedited tower completion.
- The segmentally launched sky bridge didn't require propping, enabling uninterrupted work on the podium below. Optimised construction sequencing minimised temporary diaphragm actions, ensuring an efficient and buildable structure. Innovative connection details facilitated bottom-up construction with a significant portion hanging in the permanent case.
- Façade installation utilised a temporary steel bridge platform beneath the permanent sky bridge. Innovative construction methods minimised module weights with temporary fixed cantilevered conditions, transitioned to a permanent pin-roller condition, almost halving the platform's weight, and allowed dismantling with a bridge above it after façade installation.



Opus Building - Dubai, UAE.

One Za'abeel

DUBAI, UAE
CLIENT: ALEC ENGINEERING & CONTRACTING

One Za'abeel consists of seven basements, an above-grade podium structure, and two towers connected by a horisontal link structure (dimensions: 18 metres x 18 metres x 266 metres). The two towers, at 300 metres and 240 metres tall, support the panoramic sky concourse link, which cantilevers 63 metres from the taller tower and sits 100 metres above ground level. Connected to composite columns within each tower and comprising approximately 10,000 tonnes of heavy built-up steel sections, the link features restaurants, a swimming pool, and commercial space.

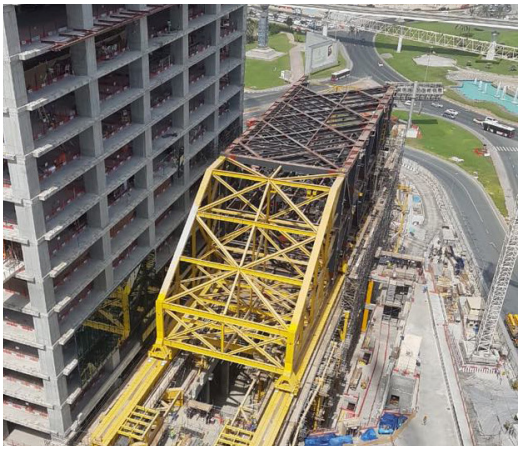
BG&E served as the third-party engineer for the contractor, verifying the link bridge's structural calculations and drawings from the steelworks contractor. Additionally, BG&E handled the design of all temporary works on-site, specifically for the link bridge construction and erection.

Safe Installation
To ensure safe bridge installation, BG&E monitored tower stresses and deformations throughout the construction program to meet strict architectural serviceability criteria. Cores and columns were pre-set out of plum based on a study of building movements.

Incremental Launch
The link bridge, fabricated on a temporary steel structure over Podium A and B, required partial strengthening. Constructed over Podium A, it was incrementally launched across a live highway, eventually seating down on the temporary structure of Podium B. BG&E coordinated significant propping through the podiums, supporting up to 20MN, to facilitate this solution.

Simultaneous Tower Construction
Originally, tower construction was planned to be halted until the link bridge was fully

welded. However, BG&E's sensitivity analysis established that tower construction could commence before lifting the link bridge. Determining the maximum floor levels to be completed during the link bridge lifting facilitated removing tower construction from the critical path, resulting in construction program savings. BG&E studies further revealed that the towers' movement was minimally impacted by the second lift. This allowed for the removal of the second lift from the critical construction path, enabling the simultaneous construction of the two towers and showcasing an innovative design outcome.

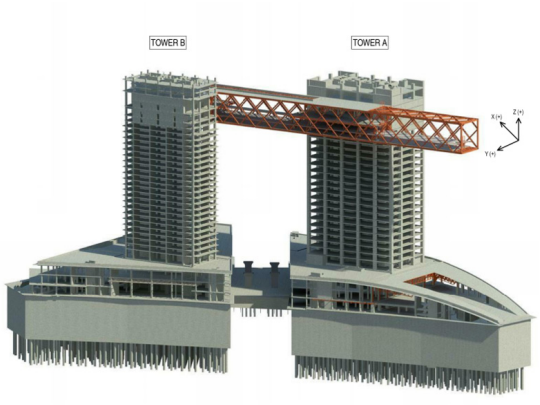


Cantilever Solution

BG&E facilitated the sliding of the link bridge 40 metres over a live highway by devising a cantilever solution, eliminating the need for intermediate support. This approach avoided additional highway closure time, extra foundation structures under the existing overpass, a crash deck, and extensive coordination with multiple authorities - reducing the time and cost of the link construction. The link bridge, lifted in two segments (7500 tonnes and 2500 tonnes), ensured that cantilever end deformation didn't prohibit welding to the towers. The second segment was lifted after fixing the first segment to the towers.

Lifting and Strengthening Solutions

During the lifting of the link bridge, extremely high loads were transferred to the towers. BG&E assisted steelworks and lifting contractors by providing several design options for the lifting gantries as well as solutions for strengthening the tower structures once the final scheme was chosen. The additional strengthening of the towers was provided using existing permanent steelwork, therefore reducing the embedded steelwork that had to be constructed on-site.



Basement Structure Construction

The close proximity of the two plots led to the construction of substantial retaining structures, such as soil anchors, waling structures, and connectors between the plots during the shoring stage. This construction clashed with a significant portion of the permanent basement structure. BG&E coordinated basement construction staging with a reduced retaining structure anchor system, optimising efficiency in building the basement structure. This minimised the presence of additional shoring contractor workers on-site for the shortest duration possible.

Qatar National Library

DOHA, QATAR
CLIENT: QATAR FOUNDATION FOR EDUCATION, SCIENCE & COMMUNITY DEVELOPMENT

BG&E was engaged by the Brookfield Multiplex Medgulf JV to provide construction engineering, value engineering and temporary works design for the construction of the Qatar National Library (QNL).

The QNL is spread over three stories with raking stadium-like terracing plus a basement level for book storage to create a structural form similar to an open book at a scale of 140m x 140m.

The OMA-designed building's façade panels are hung from the roof and have been created from a unique curved glass profile, utilizing the depth of the curve in the glass to provide structural strength and avoid the use of any mullions.

To model the roof and façade integrally, BG&E developed a staged analysis model to determine the displacements at each stage of the installation and designed the fixings to suit these tolerances during the installation of the 27m high hung façade elements.

A 3D Tekla modeling for the analysis of the roof structure for the design of the structural elements was undertaken and sent straight to fabrication. BG&E also engineered an alternative design for the raft foundation to limit excavation, increase pour sizes and enable trafficability of the crawler crane on the slab during the construction.

Qatar National Library - Doha, Qatar.

Te Kaha

CHRISTCHURCH, NEW ZEALAND
CLIENT: JINGGONG STEEL INTERNATIONAL

BG&E is providing construction engineering and temporary works services to the $683-million project - including design review of temporary propping, lifting lug assessment, trusses construction jigs, temporary stability of roof trusses, and access platforms.

The Te Kaha – Christchurch Stadium a is a state-of-the-art addition to Christchurch, set to accommodate 30,000 for sports and 36,000 for music events. The stadium promises to invigorate the city centre, spur development, and reestablish Christchurch as a sports and cultural hub - drawing visitors from around New Zealand and the world.

With the project set to span from 2023 to 2025, the design review for Christchurch Stadium presents challenges involving coordination with overseas designers and a Mandarin-speaking team, as well as addressing the designer's unfamiliarity with local codes. Effective management of critical factors such as logistics, crane availability, and tight project timeframes and time constraints is essential.

Our technical team will apply their robust earthquake engineering knowledge, 3D FEM modelling skillset, expertise in legislative requirements and local design codes, and multilingual capacity to ensure the project's success.

Data Centre - Austria

VIENNA, AUSTRIA

Situated in the Austrian capital, Vienna, the 9,750 square metre, 4.8 megawatt data centre was designed for a leading software provider. Our highly skilled team provided structural and civil design services, structural and civil site support, and temporary works design for the technologically advanced centre.

BG&E, alongside other consultants, created a data centre that is protected from natural hazards and malicious attacks, optimises energy usage and is adaptable for growth. It was delivered ahead of schedule and in accordance with local development regulations.

Data Centre - Spain

MADRID, SPAIN

Working with a dynamic team of technical specialists, BG&E designed a state-of-the-art rapid deployment data centre for a major technology company. The 7,400 square metre, 4.8 megawatt centre is located in Madrid and includes the hallmarks of outstanding security, uncompromising reliability and energy efficiency.

BG&E provided structural and civil design services, structural and civil site support, and temporary works design for the project.

Data Centre - Germany

BERLIN, GERMANY

Situated in Berlin in Germany, the 16 megawatt data centre was designed for a leading technology company. Our highly skilled team provided structural and civil design services, value engineering and temporary works design for the mega-sized centre.

Our team from London and other consultants created a data centre that is protected from natural hazards and cyber-attacks, optimises energy usage and is scalable for growth. It was delivered in accordance with local development regulations.

Data Centre - England

LONDON, ENGLAND

BG&E showcased its expertise with the temporary works design for a cutting-edge 120-megawatt data centre in London, England, commissioned by one of the world's largest technology giants. As of 2023, works are in full swing.

Our scope of temporary works services comprises:

- Structural analysis and design to ensure global stability during construction, utilising a 3D FEA staged analysis model for both structures.
- Checking and designing to ensure sufficient stiffness and strength of structure for anticipated construction loads (inc. self-weight, wet concrete, live loads, wind, notional horizontal, and thermal).
- Permanent structure checks for the temporary works design in line with the proposed construction sequence.
- Structural adequacy checks for members, foundations, and connections.
- Review of steel fabrication drawings for all temporary works design items.

At BG&E, we are united by a common purpose – we believe that truly great engineering takes curiosity, bravery and trust, and is the key to creating extraordinary built environments.

Our team of more than 1100 highly skilled people, in 15 offices across Australia, New Zealand, Singapore, the United Kingdom and Middle East, design and deliver engineering solutions for Clients in the Property, Transport, Ports and Marine, Water, Defence, Energy and Resources sectors.

OPPORTUNITIES THROUGH EXCELLENCE

bgeeng.com

BG&E

CE_DIS_CS_R2_P0824