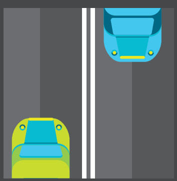
Steel Construction New Zealand Inc.
2018 Excellence in Steel Awards
Finalist Information

SH1 RUSSLEY ROAD UPGRADE



CLIENT: **NZ TRANSPORT AGENCY**

Downer

McCONNELL DOWELL
CREATIVE CONSTRUCTION™

CONTENTS

1. EXECUTIVE SUMMARY

Located near Christchurch International Airport and adjacent to SH1, this high-profile roading project, the SH1 Russley Road Upgrade, widens 3.5 km of existing state highway. At its centrepiece is the Gateway Memorial Avenue flyover and arch structure, which features a four-legged arch curving gracefully 27 m above ground-level, with its two main beams crossing directly above the carriageway.

The structure is driven by architecture, landscape, and engineering working in unison. It is expressive of the forces acting upon it - minimising structural weight and thickness, while also presenting a powerful, vaulting form which reflects the energy of the city of Christchurch. Symbolic of the crossing of paths and the coincidence of differing modes of transport, the arching, fluid form captures the dynamism, excitement and speed of travel by both land and air, and recognises the unique airport location within the alluvial patterns of the Canterbury Plains.

While the design concept itself is clean and simple, the engineering and construction to execute it was both complex and innovative, and demanded the very best skills that New Zealand has to offer. Comprising 30 sections and weighing 400 T, construction of the arch and flyover underneath provided the JV with a significant challenge for planning, safety, and traffic control.

The completed structure could not have been realised without the immense expertise, know-how, and collaboration of all parties involved. Innovation in traffic management solutions, value engineering design solutions and risk management, coupled with effective communications and stakeholder buy-in, meant that the project was completed seven months ahead of schedule and very close to the original budget. Quality is of the highest standards and the project has achieved its purpose of reducing congestion, improving safety and travel times, and enhancing the visual impact of the road corridor through the western corridor, as well as providing a unique welcome to visitors passing through the fast growing airport precinct.

Overview

THIS ROAD OF NATIONAL SIGNIFICANCE (RONS) PROJECT WAS AWARDED TO THE MCCONNELL DOWELL / DOWNER JOINT VENTURE (JV) BY THE NEW ZEALAND TRANSPORT AGENCY (NZTA) UNDER AN EARLY CONTRACTOR INVOLVEMENT (ECI) MODEL IN AUGUST 2010. CONSTRUCTION COMMENCED IN MARCH 2015 AND IT WAS OPEN TO THE PUBLIC, WITH GREAT ACCLAIM ON 11 NOVEMBER 2017. WE ACHIEVED PRACTICAL COMPLETION IN JUNE 2018 SEVEN MONTHS EARLY AND FOR A TOTAL COST OF $112M.

Fast facts

- 3.5 km of four-laning
- 4 lane Memorial gateway flyover with signalised eight lane intersection beneath
- 400 t iconic arch gateway structure, as heavy as 65 elephants
- 150 m long subway with 6 m long precast units
- 10,000 t of contaminated fill removed
- $3.3m of value engineering savings returned to NZTA
- 250,000 m^3 of fill, the equivalent of eight rugby fields, placed in the Memorial Ave Embankment
- 20,000 m^3 of cut to create the Southern Airport Access - material used in the Memorial Embankment
- 30 km of cable and 20 km of ducting
- 4,000m^3 of concrete and 130,000m2 of pavement.

Figure 1: Visually stunning day and night, the flyover is a dramatic gateway to Christchurch that enhances the city's landscape.


Figure 2: Artist's impression of the Arch

2. OVERALL DESIGN MERIT

The focus of the design was to provide a robust solution that satisfied the design requirements for strength, stability, and durability, without compromising the aesthetic notion of the arches. The winning concept comprised slender tapered dual arch structures with hangers. As design progressed, it became evident that it was not feasible for the arches to support the bridge without compromising the size and shape of the arch structure. It was finally agreed that the arch geometry would be maintained and that the bridge would be supported at mid-span by a pier.

Although the structure is referred to as an 'arch' it does not have the geometry of a pure arch. Each arch comprises a hollow box welded plate section that constantly changes in size and geometry from a diamond shape at ground level to a triangle at the crest. At the crest, the two arch structures are connected together – to provide adequate lateral bracing to the arches.

A number of options were considered at preliminary design stage to optimise the arch design. These included considering various materials (steel, aluminium and fibre reinforced plastic). The preferred solution adopted comprised steel plate sections fully continuous and integral at the foundations, with piled foundations.

Analysis of the arches was primarily performed using a 3D beam element model to which the various design loads were applied. Seismic loads were analysed using a dynamic response spectrum analysis and lateral spread applied to the foundations as imposed displacements. An elastic buckling load analysis was required due to the slender nature of the arch legs. Wind loading was more complex and this resulted in a specific wind study including wind tunnel testing carried out in USA.

The design was further complicated by the continuously changing cross-section shape, curved geometry and unbraced length of the arch legs. The design required research into appropriate British standards to determine the reduction in section capacity due to slenderness effects.

Design of the connection between the structural steel arch and reinforced concrete foundation was complex. To achieve the desired appearance, a cased pile, offset buried plinth was required. To provide the required transfer of forces at this connection, the bottom section of the steel arch has internal shear studs, a heavy internal reinforcing cage (continuous from pile cap into the arch section) and is concrete filled.

Detailing of the arch to provide the required buckling stiffening to the face plates and fatigue performance without compromising fabrication requirements, transportation limitations and erection requirements, all required careful consideration. Determining the required pre-camber shape, also required detailed staged analyses accounting also for the temporary support conditions and order of installation.

The key buildability issues of the steel reinforced pier centred on the very tight tolerance of steel reinforcement detailing. This was achieved using steel templates for setting the reinforcement foundation for the 3 m deep pile caps and the steel pier foundation plate. Parts of the Y pier involved 80 mm plate.


Figure 3: Steel reinforcement placement


Figure 4: Placement of south abutment upstand and deck starter reo

3. CONSTUCTION EFFICIENCY AND QUALITY

3.1.1 Quality

Our quality commitment was underpinned by a culture that fostered and stimulated appropriate behaviour and excellence to successfully drive a high level of conformity to specification. Quality was a central component of every key decision process we undertook, including the selection of steel fabricators, Eastbridge. NZTA was party to the fabricator selection, attending the interviews of the potential partners. We understood that our suppliers' track record could make the difference between 'right first time' and repeated re-work. As such, pre-meetings with Eastbridge clearly outlined the expected quality outcomes prior to starting the works. Internal quality audits were undertaken at Eastbridge's facilities, by our Quality Advisor and SPM to ensure compliance with the project specifications. Interfacing with Eastbridge in the preparation of their Quality Plan and ITP resulted in successful completion of the project that has exceeded client requirements.

Various materials: steel, aluminium and fibre reinforced plastic were all considered at concept .The use of steel material gave advantages with extremely high onsite tolerances. When joining the 30 x 18m segments together we were limited to <5mm misalignment between the structural face plates. Local trial fits and survey between 18m segments were conducted in the workshop where programme permitted, but a full global trial fit of all members was never an option so there remained inherent risk of misalignment in certain locations. Steel gave us the ability to locally modify the face plates on-site in order to achieve these tolerances that would not have been possible with concrete.

3.1.2 Construction

The Hendon Bridge at Waterview provided an opportunity to re-use the significant trestle on the Memorial Arch. Substantial temporary works and permanent bridge checking was undertaken to ensure that the bridge was not overstressed during the final welding of the arch when huge leg forces would be generated

During delivery, we undertook strategic procurement to safeguard the programme, provide flexibility, and insulate other works from the Arch and Memorial Avenue Bridge redesign. .The Kaikōura earthquake added a substantial logistics challenge to delivery to manage the complexities of design, procurement, and site activities we used Primavera P3 for scheduling the works. Which facilitated critical path programming, earned value analysis, activity project controls and progress reporting.

Teamwork and communication were imperative for the installation with the JV providing the craneage and Eastbridge the riggers and welders. The erection was only one of many other project tasks being performed concurrent within the tight site. With Garden City Helicopters adjacent to the Memorial Avenue Bridge a coordinated approach was needed to ensure a safe crane operating area and a safe flight path. Following discussions, the GCH, their pilots enjoyed a bird's eye view from the crane operator's seat, as did the crane drivers from the pilot's position. This helped galvanised a safe and successful working regime. A significant reprograming exercise was also undertaken with the adoption of deletion of the ground improvement works, incorporating the redesign of the Arch and Memorial Avenue Bridge and the ovalabout.

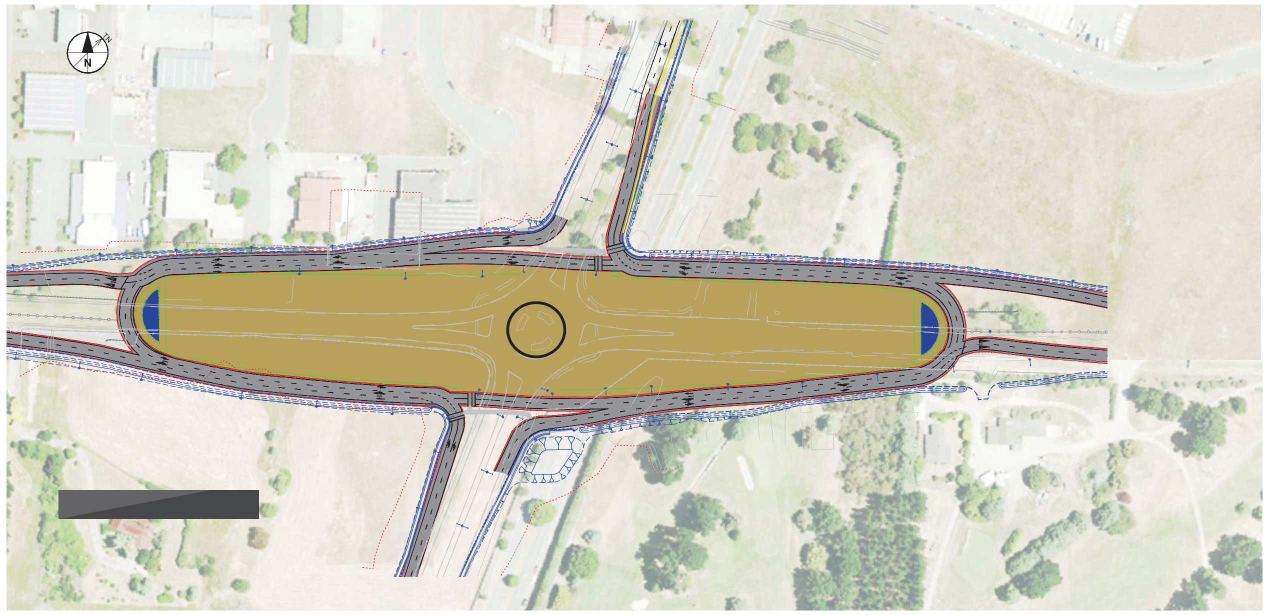


Figure 5: The ovalabout provided a safe site for both our team and motorists

Figure 6: Aerial of the project looking toward the airport and Gateway Memorial Bridge in the distance

4. ENVIRONMENTAL SUSTAINABILITY

Following a series of optioneering reviews, custom fabricated steel sections were identified as the only material option in order to achieve the Architect's intent and meet the design requirements identified by Aecom. Their slenderness prohibited the use of pre or post tensioned concrete that would have been bulky and imposing, as well as contrary to the Warren and Mahoney slender arch solution. To ensure that the development of the construction methodologies was not impairing this Vision, the Joint Venture brought Peter Marshall, MD of Warren and Mahoney, into its project team. A significant aspect of the final arch appearance is the feature lighting which illuminates the structure every night. Fifty-two light units are strategically but empirically located around the arch on the embankment, aligned so as not to impair driver's vision adjacent to and crossing the embankment

The paint system was developed with the Joint ventures designer Aecom and Eastbridge's coating partner Napier Sand Blasting and reviewed with NZTA and its advisors. Being located near the CIA consideration for contamination from air fuel is provided for in the design solution. This also included due consideration of future cleaning and maintaining of the arch. An anti-graffiti barrier was included in the paint system

The issue of anti-climbing measures was duly considered over quite some period and the final solution was to incorporate a concealed fixing system into the arch faces and develop a suitable set of anti-climbing measures to prevent and dissuade attraction to the arches. A risk assessment for support this approach was undertaken and supports the adopted solution

The substantial trestle unit for supporting the arch build originated in Auckland as it was originally used for the new Waterview, Hendon footbridge construction. Following its pivotal contribution on the arch build the trestles are now being used on the CSM2 construction

Figure 7: View from the North

5. BUILDABILITY

5.1.1 Constructability The team worked collaboratively to piece together a very unique puzzle, at height and to a regular audience of 50,000 vehicles a day.

We applied a rigorous design review process, which enabled constructability reviews to be carried out during the detailed design phase and for the redesign of the Gateway Memorial Avenue flyover and arch during construction. This process helped to identify areas where special control measures would be required to ensure construction would be right first time despite the complexities of manufacture or associated methods of construction Methodology

Detailing of the arch to provide the required buckling stiffening to the face plates and fatigue performance without compromising fabrication requirements, transportation from Eastbridge's fabrication yard in Napier, and erection requirements, all required careful consideration. Determining the required pre-camber shape around the temporary arch towers, which is built into the fabricated shape of the arch, also required detailed staged analyses accounting for the temporary support conditions and order of installation.

Construction and erection "Lessons Learnt" from the Hendon Footbridge on the Waterview Project were provided in the Erection Risk Workshop to help the Project Team develop its erection methodologies. A temporary trestle was provided for the arch installation, used originally to construct the Hendon Footbridge.

5.1.2 Value Engineering

Design factors were reviewed and agreed collaboratively with the NZTA and the ECI team during a Value Engineering phase including the Importance Levels of the bridge and arch (which reduced from 3 to 2), seismic criteria, soil parameters, and pile ductility design factor. Other impacts were discussed, which took into account the change in design relating to the Value Engineering solution agreed for treatment of the Brevet Landfill under the embankment, and a change in embankment stone specification from a standard AP65 to a modified crushed face AP65 to assist with stability of the embankment.

The resultant design was thoroughly reviewed at every stage providing a cost saving to the NZTA of $1.8M. The redesign phase was undertaken over a 36 week design period without generating an extension of time.

5.1.3 Arch modelling

The arches are the most geometrically challenging structure that Eastbridge have ever constructed. To have a section profile that morphs from a four-sided diamond into a three-sided triangle combined with progressive axial rotation was unprecedented example e.g. 40mm G350 L15 plate required bending in two directions.

Four members were left to last as crucial drop in segments. These were custom lengths to fit gap-close locations at the end of arch installation.

Reinforcement installer and partner Complete-Reo assisted in the visualisation and development of a highly complicated skew pier head and abutment layout. Using 3D software they were able to provide a very effective installation priority visualisation for installing the complicated reinforcement.

Arch modelling also incorporated the Memorial Avenue Bridge Fairing and TL3 concrete barrier detailing to provide a visually flowing, but functioning concept. This enabled Eastbridge, to establish its own Solid Works mode to enable the various complex components to be analysed and developed into buildable structural forms.

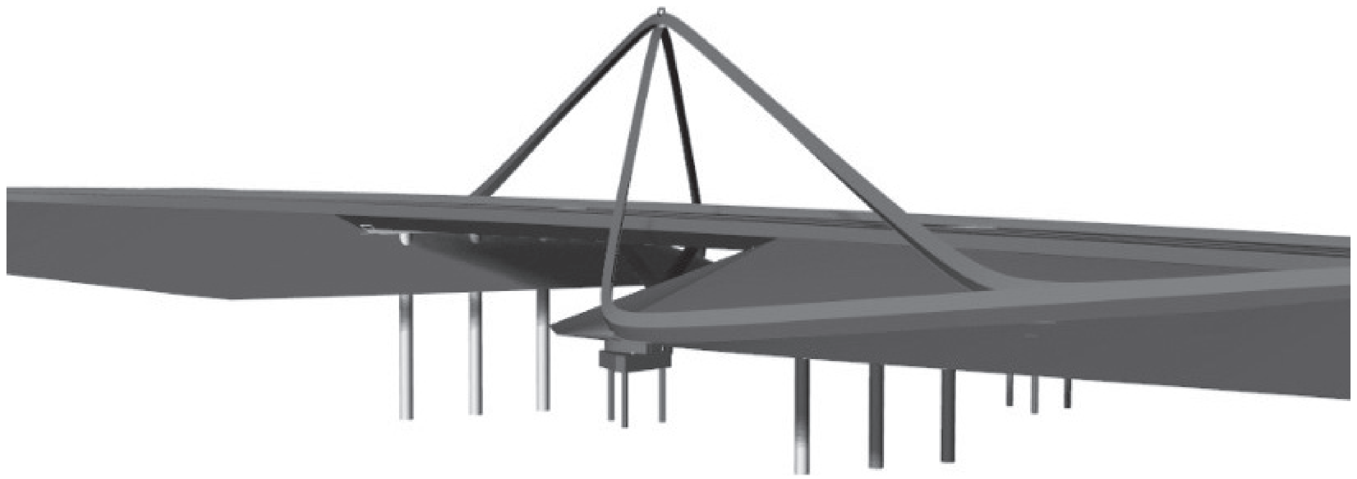


Figure 8: The Memorial Arch

6. INNOVATION IN FABRICATION AND CONSTRUCTION

6.1 Fabrication

A risk based approach was undertaken aligning NZTA, JV temporary works designers, Eastbridge, and designer AECOM, to identify the risks and difficulties of the construction. A measured risk assessment was undertaken and updated weekly to reduce the risk profile .

A simplistic approach was adopted to achieve the twisting shape profile. A central dummy spine member per 18m segment was adopted as a reference and each incremental rib/diaphragm was cut to an exact profile and positioned at their respective unique longitudinal positions. With this skeletal frame laid out, the skin plates were able to be laid on and FSBW joined. Twisting of the sections was a challenge throughout the fabrication

Cost savings were made post-design by offering alternative weld details and swapping out heavy section fabricated cruciform ribs with simple plate diaphragms.

Working in a live traffic environment was a key safety focus with a series of service improvement measures implemented during the project.

Figure 9: First knuckle going into place

Figure 10: First vertical section in its place on its saddle

6.2 Complexity of construction

Construction was complex due to the 30 separate sections that comprise the two arches (steel Y-pier) being fabricated in Napier, transported by road to the site, and erected over a four-month period. Each section has been welded together piece by piece. Nineteen metre towers were used as a base for the welding and steel work to be completed. 3D BIM models were critical in both design and construction phases due to the complex geometry and tolerances required. Due to the reinforcing complexities, steel fixers were flown from Christchurch to Eastbridge's fabrication yard to install the internal reinforcement prior to the final welding of the arch skins.

The complexity of the steelwork foundation and fit with the pile cap required two 'married' steel templates to enable the ± 3 mm accuracy of fit to be achieved.

Arch sections began arriving on site in December 2016 and in January the project team began locking a 23-tonne 'knuckle' into place, the first of four. The knuckles are the most vital parts of the structure, creating the curve and intersections for both arches and connecting them with the supporting piles in the ground. Four separate concrete pours were involved in knitting the pile cap to the arch section, which itself was filled with concrete at this location. Such was the density of reinforcement that internal lighting was provided for the pre-pour checking.

An alternative traffic management arrangement was developed, to provide a clear safe space within the intersection for construction of the Memorial Avenue Bridge and arch and keep the traffic moving efficiently around the works. The JV provided a solution which was effectively a large elongated roundabout. This fully detailed design provided three circulating lanes over a length of just over 500 m and two signalised intersections with substantial stacking capacity to allow for peak flows. This type of intersection had not been used before in New Zealand. A structured and very controlled pedestrian route was provided by providing secure containerised walkway units.

Figure 11: Temporary Works

Figure 12: The final piece of the gateway arches going into place

"The finished highway and structures has achieved its purpose of reducing ongestion, improving safety aand travel ties, and enhancing the visual impact of the road corridor through the western corridor.

The new road was opened to the public on 21st May 2018, some seven months ahead of schedule and very close to the original budget.

We enjoyed a good working relationship with the JV throughout this contract and their commitment to the local community enhanced our performance as a project team."

Chris Collins, Senior Project Manager, NZTA

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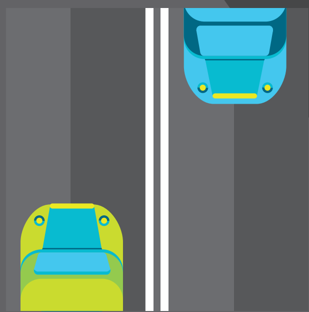

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