CANADA STREET BRIDGE
NELSON STREET CYCLEWAY

MARCH 2018

# STRUCTURAL STEEL ENABLES WORLD-FIRST BRIDGE DESIGN

The award-winning Canada Street Bridge is a world-first: it's the only curved, triangular orthotropic steel bridge of its kind.

Part of Auckland's Nelson Street Cycleway, the unique structure was built to fulfil the NZ Transport Agency's (NZTA's) vision of providing world-class cycling infrastructure throughout each major town and city in New Zealand.

'Bikes over the bridge by Christmas' was the objective set in October 2014. In just 14 months, 300 tonnes of steel were expertly engineered, fabricated and installed in a 160m-long, 4m-wide cycleway.

Located amid the Central Motorway Junction – the country's busiest and most complicated section of highway infrastructure – this was no easy feat.

The success of a project of this scale demanded innovative thinking, cutting-edge structural analysis and 3D modelling of an extremely complex structure and, most of all, collaboration.

A time frame-driven attitude by all involved was essential to deliver the programme within the tight timeframe, which was achieved thanks to a colossal effort from the team of designers, fabricators and contractors.

This effort has seen the project win 19 awards, including the Supreme Overall Winner in the SCNZ Excellence in Steel Awards 2017.

Together, the team transformed the world-first design into a reality. Today, the Canada Street Bridge has created a stunning, interactive urban space.

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## THE FACTS

- World's first curved, triangular orthotropic steel bridge
- 160m long, 4m wide
- 300 tonnes of structural steel
- More than $3.5 million worth of fabricated structural steel sections
- Average mass of structural steel of 1.35tonne/m run of deck
- Heaviest beam 109 tonnes and 54m long
- 14 months from concept to delivery
- Seven spans, the longest being 39m over SH1
- 5 horizontal curves of different radii
- 40 years until first major maintenance
- Award-winning bridge, 19 times over
- A seven-time finalist, including in the World Architectual Festival 2015 for Infrastructure Future Project

**OWNER:** NEW ZEALAND TRANSPORT AGENCY **DESIGN TEAM LEADER AND STRUCTURAL ENGINEER:** NOVARE DESIGN
**ARCHITECT:** MONK MACKENZIE **STRUCTURAL STEEL CONTRACTOR:** PFS ENGINEERING **MAIN CONTRACTOR:** HAWKINS INFRASTRUCTURE

Courtesy of Tammy Williams

**"THE CANADA STREET BRIDGE'S SINUOUS, ELEGANT AND SIMPLE AESTHETIC BELIES THE TECHNICAL COMPLEXITY IN ITS DESIGN, FABRICATION AND CONSTRUCTION. THE WELL THOUGHT THROUGH PROJECT TICKED MULTIPLE BOXES, INCLUDING ITS SPEED OF CONSTRUCTION, COST EFFECTIVENESS AND MINIMAL IMPACT ON THE ENVIRONMENT."**

– DUNCAN PETERS, ENGINEER, NOVARE DESIGN

The bridge's geometry includes horizontal and vertical curves, haunching, pre-cambers, and changing gradients, spans and supports. As a result, the steelwork incorporates a total of five horizontal curves, two vertical curves and a varying longitudinal gradient. Despite the complexity, steel enabled a slender design, which delivered structural elegance and little disruption to the city's landscape.

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## ENGINEERING

Functional, elegant, economical, buildable, low maintenance, and built in the shortest possible time frame: these clear requirements demanded a clever engineering solution for the Canada Street Bridge, led by engineer Novare Design.

From the outset, Novare envisioned a bridge that would delight users and set an aesthetic benchmark for future neighbourhood developments.

First and foremost, the design was dictated by practicality. The original brief from NZTA was to build a straight bridge from South Street to the Nelson Street off-ramp, but it needed to suit the end user: cyclists. It meant the structure would have to curve over the motorway to provide a seamless cycling experience.

While Novare was not committed to steel from the outset, the resulting long, curved span over the heavily trafficked motorway meant that a steel box girder was, unquestionably, the best way to go.

At its northern end, the bridge begins at the old Nelson Street off-ramp, follows the southbound carriageway of State Highway 1, and weaves between buildings and the motorway to connect to Canada Street.

The assembly of thin steel plates, which make up the isotropic deck, allowed the bridge to be constructed to follow the smooth, sinuous cycleway, which means no sharp corners or surprise turns for cyclists, despite its complex geometry. To ensure seismic stability, the steel spans and the main pier are joined together to stiffen and strengthen the structure.

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What's more, the curved form means the bridge must allow for additional stresses. This inspired the closed-cell isotropic deck – a structural system where loads are supported through an object's external 'skin', like an egg shell. The outer steel 'shell' of the bridge – just 12mm thick – allows the stresses to flow through it unobstructed, while ribs running along the inside of the 'shell' provide extra strength and buckling resistance.

The use of a lightweight steel deck also ensured that the Nelson Street off ramp – upon which the northern end of the bridge is supported – was not overloaded.

## ARCHITECTURE

Novare Design engaged architects Monk Mackenzie, who provided valuable architectural input and quickly understood the project's need for practicality.

There was no need to 'dress steel up'. A functional material, steel can be welded and sculpted to achieve the perfect finish.

Practicality aside, the team saw an opportunity to design something more than a typical bridge.

The site, in Auckland's inner city, inspired a sculptural form to reflect the gritty urban surroundings. The pared-back aesthetic


The Canada Street Bridge is visually unique. Whether driving underneath and looking up, or stepping onto it above the traffic, the view is dramatic from all angles.

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**"NO OTHER MATERIAL WAS CONSIDERED FOR THIS PROJECT; STEEL WAS THE BEST OPTION."**

– DEAN MACKENZIE AND HAMISH MONK, ARCHITECTS, MONK MACKENZIE

**"THE HUGE COLLABORATIVE EFFORT PUT INTO THIS PROJECT SAW OUR COMBINED EXPERTISE WORK TO ITS BEST POTENTIAL, PARTICULARLY WHEN WORKING WITH STEEL. THE NATURE OF THE PROJECT DEMANDED A HIGH LEVEL OF TECHNICAL ABILITY WITH STEEL AND OUR PARTNERSHIP ENSURED THE BEST POSSIBLE USE OF THE MATERIAL."**

– GRAHAM MCKELVEY, STRUCTURAL STEEL CONTRACTOR, PFS ENGINEERING

effortlessly combines architectural form and structural integrity.

Visually, it's unique. It is uncommon to come across a steel bridge with multiple curves, but Canada Street Bridge's narrow, triangular base is especially exceptional. Whether driving under the bridge and looking up at the unique triangular form or stepping onto the bridge seven meters above the traffic, the view is dramatic from all angles.

The sculptural elegance of the bridge can be found in its cross-section, which has a depth of 1,500mm at the main piers and tapers to a shallow 800mm mid-span.

## FABRICATION AND ERECTION

With more than 300 tonnes of steel in a complex geometrical environment, a high level of technical expertise with the material was required.

PFS Engineering and Hawkins Infrastructure already had a track record of collaborating on bridges – the pair worked together on Point Resolution (Taurarua Footbridge) and the University Link Bridge. Both award-winning projects were recognised for their innovative use of steel. This knowledge was neatly transferred to the Canada Street Bridge.

This project required fabricated steel tailored specially for the unique design. After design and procurement was complete, there were only six months available for fabrication. PFS dedicated a large team of skilled tradesmen to a 24/7 operation.

PFS used Novare Design's 2D engineering drawings to produce a 3D model, enabling computer-controlled cutting of the curved steel plates. The model served as a literal reference for PFS, who relied on it to cut every piece of steel.

The distinctive, triangular-shaped bridge required a fabrication approach similar to boat building. First, the skeleton frame of the I-beams, diaphragms and ribs were assembled, with the deck on the floor and the V shape elevated. Then the skin was fitted to the V before the beam was turned over to enable the deck and handrails to be welded in position.

Each joint between beams took a week to weld, while a weather tent protected this work to support its completion.

Precision was impressive – the bridge beams and piers were fabricated within a 1mm tolerance of the 3D model. The handrails draw the eye of cyclists and pedestrians, their skilled fabrication ensuring a smooth finish to follow the curving bridge.

And thanks to the corrosion protection system specified for the bridge's deck and piers, maintenance on these elements won't be required for 40 years. The system consists of a 150-micron-thick layer of thermal sprayed zinc, a seal coat system comprising 75-micron-thick epoxy zinc phosphate primer, and a 75-micron-thick glossy black acrylic polysiloxane top coat. Polysiloxane has proven resistance to weather, and excellent colour and gloss retention. Notably, no corrosion protection was required inside the hermetically sealed box girder and piers.

Building a cycleway does not involve a typical construction site. This one was being fit into an active landscape, between buildings and over roads, which made access and manoeuvrability a challenge.

**"THE CYCLEWAY IS A JEWEL IN THE AUCKLAND CROWN, IN FACT MORE THAN THAT, IT IS THE MOST AMBITIOUS CYCLE PROJECT EVER TO OPEN."**

– SIMON BRIDGES, FORMER MINISTER OF TRANSPORT

**"THE TRUE SUCCESS OF THE PROJECT LIES WITH THE NON-PRICE ATTRIBUTES – IT WAS ALL DOWN TO THE TEAM. THE HISTORY OF COLLABORATION AND THE STRENGTH OF THE COMBINED TECHNICAL ABILITY WITH STEEL, DELIVERED THE PROJECT BEYOND OBJECTIVES."**

– GREG DEWE, PROJECT MANAGER, HAWKINS INFRASTRUCTURE

## CONSTRUCTION

Hawkins Infrastructure had the ultimate responsibility of constructing the project on time and within budget.

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The sloping and poor ground conditions posed further construction challenges for site preparation. Hawkins Infrastructure's experience with similar projects enabled the smooth site works, which saw the complex project delivered expertly to meet the tight programme.

Partnering with PFS Engineering, Hawkins Infrastructure oversaw the structural steel fabrication from a construction perspective, referring to the 3D model that dictated how each section of steel would be pieced together on site.

The lightweight isotropic steel box girder deck and speed of steel construction were integral to the project's success. The steel beams, made in parts, allowed the bridge's continuous, flowing alignment.

Disruption was a key consideration – the bridge was to be built over one of the busiest highways in New Zealand. How do you construct a bridge without stopping traffic?

Off-site fabrication was the solution. Structural steel sections were constructed in discrete parts in the factory. The length of beams fabricated was dictated by what could be safely transported down the motorway. Once constructed, the sections were easily transported to site and assembled.

The longest beam spanning the motorway was 54m, which was too long to transport to site. The solution was to weld three beams together on a prepared platform adjacent to SH1 and shut the motorway overnight to lift the 109 tonne bridge beams into place.

Several environmental considerations were taken into account in the design and construction of this bridge. For example, the steel deck and piers meant minimal earthworks were required in contaminated land during winter. And the steel structure minimised the risk to protected pohutukawa trees, and enabled the planting of New Zealand natives on the steep banks and under the bridge to reduce erosion.