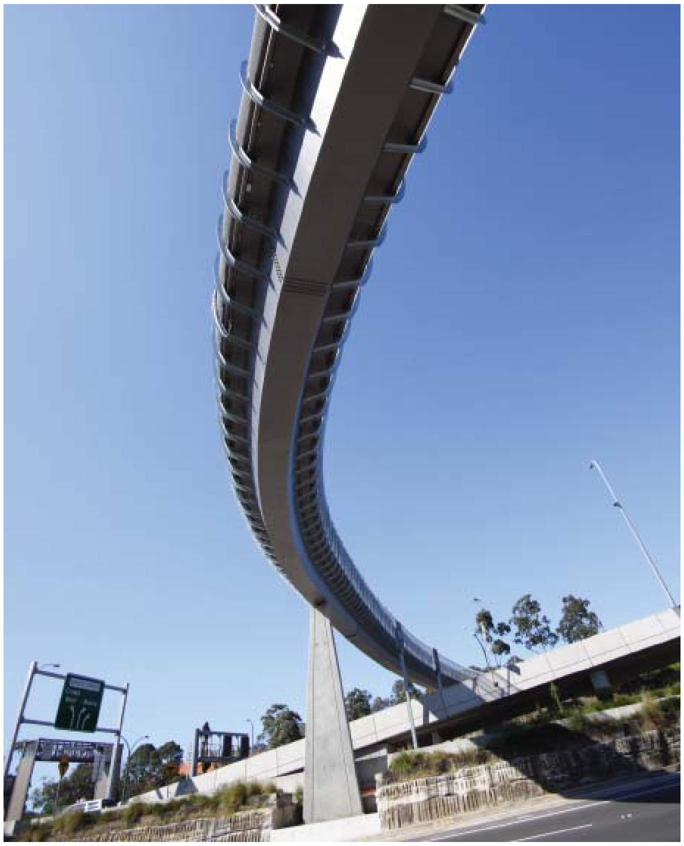
FALCON STREET FOOTBRIDGE

STRUCTURAL ENGINEERING AWARD 2010 - MINING + INFRASTRUCTURE

NATIONAL AND STATE WINNER (NSW + ACT)

Aurecon Australia + RTA



Design

The new Falcon Street Pedestrian Bridge is a curved, continuous steel box girder structure which allows unimpeded access for pedestrians and cyclists across nineteen lanes of the Warringah Freeway north of the Sydney Harbour Bridge. This Roads and Traffic Authority NSW (RTA) project involved extensive stakeholder consultation to determine the best location and alignment to suit community needs. The specific site constraints dictated a continuous long span steel box girder structure, curved both in plan and elevation as the best solution.

The bridge is comprised of five spans of approximately 193 m in total length. The span configuration is 15.7 m, 36 m, 66 m, 65 m and 10.3 m. The bridge has a 3.0 m clear width in accordance with AS5100.1 for Shared Use Paths.

After an extensive review of options a trapezoidal steel box girder option was selected by the project stakeholders based on the following criterion:

- The ability for the steel box girders to be used economically in long spans as opposed to a concrete or composite section
- The speed and ease of erection required
- The aesthetic appeal and reduced maintenance specified by the client
- The fact that steel box best facilitates the curved horizontal and vertical alignment

The superstructure is a 1500 mm deep fully welded trapezoidal orthotropic steel box girder. The deck slab has an anti-skid corrosion protection coating that accommodates pedestrian and cyclist traffic across the bridge. Provision was made in the design for the installation of Tuned Mass Dampers (TMDs) to negate dynamic effects due to the slenderness of the bridge structure. Minimising the overall structural depth was a key design consideration to meet the project constraints.

Efficient use of steel products

By minimising the overall depth of the structure and producing a slender structure with a span to depth ratio of 43, the design is cost-effective and minimises the quantity of steel required. The bottom flange of the box girder varies in thickness over the length from 16 mm to 36 mm, while the top flange remains a constant 20 mm over the entire length of the bridge to carry the pedestrian traffic, and did not require transverse or longitudinal stiffeners, thus significantly reducing the cost.

An anti-skid surface treatment was detailed to the top flange of the steel deck that would also act as protection against corrosion. This anti-skid surface mitigated the need to place a reinforced concrete slab topping which would have resulted in increased costs to the client and safety risks to road users on the busy Warringah Freeway.

Each girder segment was designed to be lifted into place as a complete unit with all balustrades and anti-throw screens secured prior to lifting into position. Minimal works were therefore required to complete the bridge over live traffic.

Welded and bolted connections were carefully detailed to maximise efficiency and minimise cost. Each splice connection between the girder segments was bolted. Our design allowed the splice joint to be completed during the scheduled road closures which reduced the safety risks and cost.

Practicality in fabrication + erection

The configuration of the Warringah Freeway was the key consideration in the erection sequence developed during the design phase. The steel superstructure was placed in six separate segments commencing from each abutment with an infill span completing the bridge. In consultation with the construction team and steel fabricator a number of features were designed and accommodated into the box girder to facilitate the completion of the bridge. These features included:

- Matching each girder segment to the previous segment before leaving the fabrication workshop. This ensured that each splice connection would be a perfect match on the night the girder segments were installed.
- Modifying the top flange connection at the splice joint enabled the launched girder segments to rest on the previously installed segment whilst the bolted splice connection was being completed.
- Using purpose built temporary steel jacking frames at each pier location. These provided a means of adjusting the box girder vertically, horizontally and rotationally to match the design alignment and to ensure the next girder segment would fit accurately.
- Designing a pull system across the final splice connection to allow the gap between girder segments to be closed on the night of installation if required.

A top flange plate connection was designed at the splice points so that once the first girder segment had been placed, the next girder could then rest on the end of the first girder whilst the bolts within the splice joint were being torqued up. This enabled the crane to be demobilised before the bolted splice joint was fully completed. This connection modification reduced the risk of exceeding our time limit for the road closures and provided a safer method of completing the splice connection.

A web connection was used instead of a bottom flange to provide a more cost effective weld detail which still maintained clean lines along the bottom flange to meet the architectural requirements.

Innovation

Superstructure slenderness
Since the actual damping for the structure could only be ascertained once the bridge was built, provision was made during the design phase for the installation of Tuned Mass Dampers (TMDs) at the anti-node points if required post construction. This methodology allowed Aurecon to keep the slenderness ratio high and meet the urban design requirements as well as all other project constraints including maintaining vertical clearances to the traffic ramps below, shallow grades for disabled access and minimising material and transportation costs.

Tuned mass damper design
Since there are no manufacturers of bridge TMDs within Australia, it would be standard practice to outsource the TMD design to a company in Europe or America. However it was considered that this could be done more quickly, cheaper and more effectively by the project team. Specialists from Heggies Environmental Engineers and Scientists were engaged to provide parameters for Aurecon to confirm the design of the TMDs. As a result, the TMD was completed in only seven weeks and the dynamic performance of the bridge was above the critical range of 2.2Hz for pedestrian loading.

Bridge articulation
There are two 65 m spans within the bridge which is amongst the longest of its type in NSW. The horizontal curvature within the deck provided challenges for the design team in terms of resolving the torsional forces along the length of the bridge due to the various loading conditions.

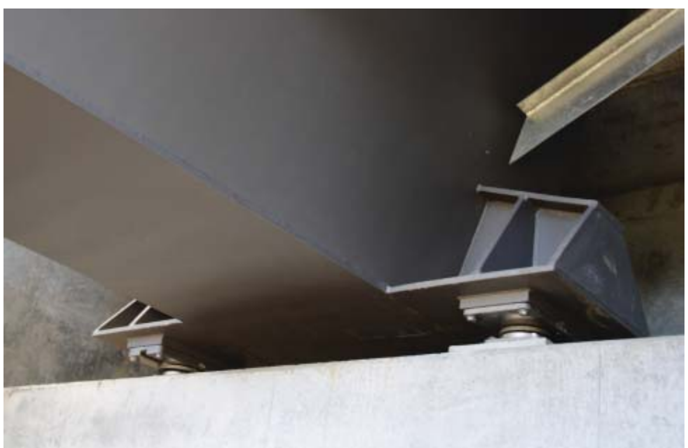
One of the architectural requirements was to minimise the pier size. This requirement dictated the plan footprint of the pier at the bearing level to be only 1000 mm by 600 mm. This was not large enough to provide two bearings to resolve the torsional forces along the length of the bridge. The design solution provided was to install two bearings at each abutment with steel outriggers to resolve the torsional forces along the bridge. A single pot bearing could then be provided at each pier to enable the architectural requirements to be met.

Pedestrian railings and anti-throw screens

Our team developed a unique steel pedestrian barrier that obviated the need for balusters and provided a clean, user friendly appearance and facility. Curved tee sections fabricated from flat plates supported the 900 mm high pedestrian railing and 1300 mm high cyclist guardrail. For the lower pedestrian barrier a 70 mm by 9 mm aperture mesh was specified and for the upper throw screen a 70 mm by 22 mm aperture mesh was adopted. The throw screen was deemed not required to be fully enclosed for urban design reasons and a sense of enclosure magnified by the length of the bridge.

Splice joints in deck

As a continuous steel box girder structure the bridge comprises a clean, joint free appearance. It was especially important that this effect be maintained in the top surface of the bridge deck which also acts as the top flange for the bridge. An innovative, purpose designed bolted splice was developed for the top plate to allow bolt heads to be fully flush with the wearing surface once installed. This also permitted the skid resistant finish to completely hide the bolt heads.



Efficient design of structure to suit application

Providing a shallow steel box girder was key to meeting the client's architectural requirements as well as the site constraints. The bridge crosses two new off-ramps from the adjacent Falcon Street road bridge where the minimum vertical clearance of 5.4 m needed to be provided. Coupled with minimising the vertical grades on the bridge to meet with the access and mobility code requirements, a structural depth of 1.5 m was adopted. This resulted in a span to depth ratio of 43 and a slender visually appealing superstructure. Usually a span to depth ratio of 25 to 30 is adopted.

For slender structures, dynamic performance is critical to functionality. For this bridge, dynamics were identified in the dynamic requirements of the Australian Bridge Code. Instead of design stage as a potential issue, although the design satisfied the length whilst maintaining the aesthetics of the superstructure. increasing the depth of the structure, thus increasing the costs, and compromising on the aesthetics, provision was made in the design for TMDs to be installed after the bridge was constructed. This proved to be a more efficient design method compared with increasing the depth of the girder and it also fulfilled the project constraints. This provided a cost saving for the client by minimising the amount of steel required over the entire bridge.

The bottom flange of the box girder varies in thickness over the length of the bridge. The transition between flanges was detailed such to provide a clean line along the soffit of the bridge with the change in thickness being accommodated on the inside of the box girder. This met the aesthetic requirements and allowed the overall cost of materials to be reduced by providing an efficient design.

The welded and bolted connections were carefully detailed to maximise efficiency, minimise cost and enhance the safety of the construction method to complete the bridge. In addition, finite element analysis methods were adopted for the design of the diaphragms to optimise the plate sizes and confirm the design stress flows from the girder webs to the bearings.

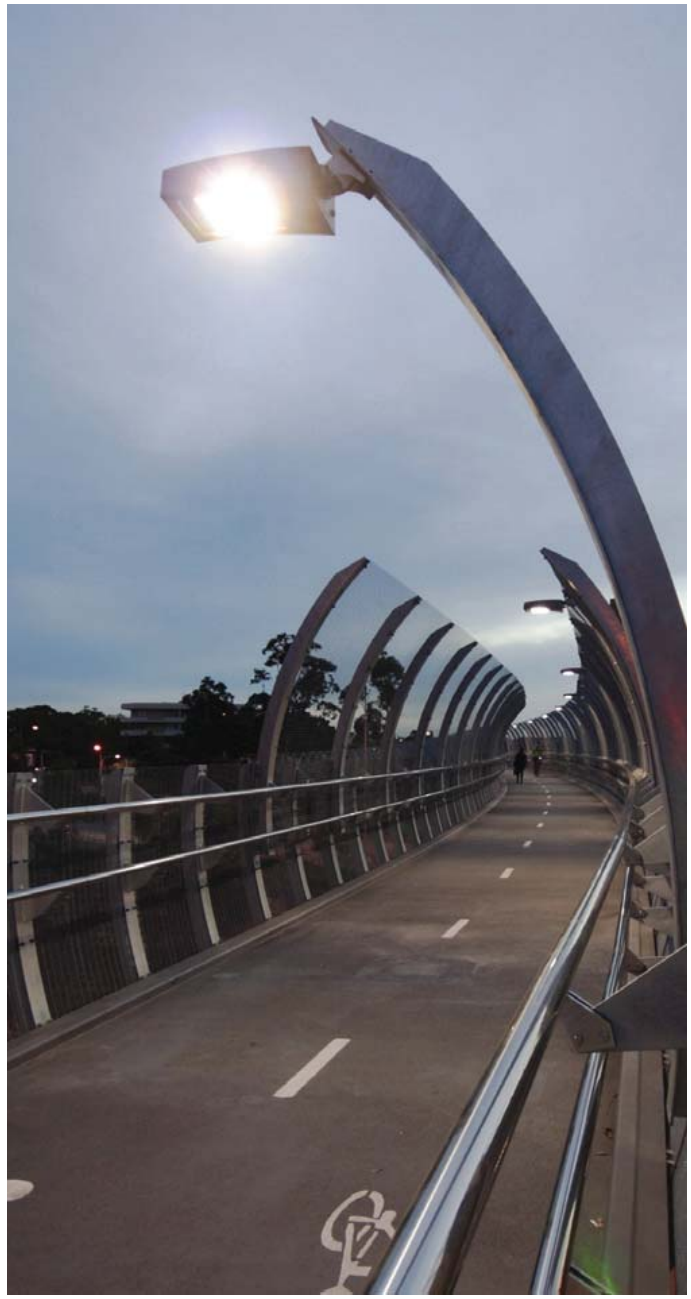
Attention to corrosion protection

Corrosion protection to the inside of the box girder was an important consideration due to the close proximity of the project to Sydney Harbour. Traditionally, the inside of steel box girders is painted and provision is made for regular inspections and future repainting when the need arises. Aurecon's design departs from this traditional thinking through the use of welded steel bulkheads applied in the shop to seal the inside of each box segment. Access openings are provided along the length of the box girder at the splice and at the location of the TMDs. This allows inspection and maintenance to be undertaken. These openings also provided access during construction.

The corrosion protection adopted for the bridge girder was to RTA Specification B220, system SC1. A specific paint system was developed by the design team in consultation with RTA Bridge Technology for the deck surface treatment comprising an anti-skid treatment that was compatible with System SC1 used for the rest of the girder.

The anti-throw screen posts are hot dipped galvanised with the anti-throw screens and balustrade screen powder-coated. This reduced the amount of painting and ongoing maintenance on the structure for these intricate steelwork elements and provided a contrast in steel colours and textures along the bridge.

The abutments at each end are detailed to provide clear access around the end diaphragms allowing for future maintenance to be undertaken to the box girder, bearings and expansion joints when necessary.



Sustainability

The overall depth of the bridge structure was minimised to reduce the amount of materials required. The strength to weight ratio of a steel box girder is very high and, in the design, the thickness of the individual plates that comprised the girder was varied depending on the strength demand at each location. By optimising the design and reducing the materials, production and transportation requirements were reduced.

Specifying a steel box girder with an orthotropic deck eliminated the need for a concrete deck slab. A concrete deck slab would have significantly increased the weight of the structure, requiring more materials. By eliminating the concrete deck slab, the carbon footprint of the bridge was reduced. A special anti-skid coating was applied to the steelwork which acts both to protect the deck surface against corrosion and to make it trafficable for members of the public.

The bridge lighting has been carefully designed to maximise energy efficiency as well as work in harmony with the architectural design of the structure.

Around the abutments and piers of the bridge, landscaping was created with native plants and vegetation.

Project team

Client:	Roads and Traffic Authority of NSW
Architect:	Kiah Infranet
Structural Engineer:	Aurecon Australia
Head Building Contractor:	Reed Constructions Australia
Steel Fabricators:	Adua Engineering (Box Girder), Rebuild Welding & Fabrication (Miscellaneous Steelwork)
Steel Detailer:	3D AccuDraft
Coatings Supplier:	International Paint
Metal Building Contractor:	Reed Constructions Australia