Iconic Twins - Two Pedestrian Bridges – Kellyville

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ABSTRACT

With the rapid development of Sydney's outer suburbs, Kellyville has undergone a transformation with numerous residential and commercial developments along with the associated road and network infrastructure. The Two pedestrian bridges in Kellyville are vital links in the North-South pedestrian and cycleway corridor crossing two of the main arterial roads in the area, Windsor Road and Memorial Avenue.

Beca Urban Designers and Structural Engineers worked closely with the council client to achieve an aesthetic, robust and sustainable design that allowed for future expansion of the road network and minimal impact to nearby residents. The form of the bridges were chosen as a light-weight steel portal truss for the main spans with in-situ concrete approach ramps with an emphasis on smooth curves and a seamless transition to the surrounding community known as Sydney's garden shire.

This paper outlines how innovation in design and construction methodology nurtured a solution that transformed one of the simplest bridge forms into two seamless, flowing, income producing architectural symbols in the area.

Figure 1 - Urban Designers Render of Windsor Rd Pedestrian Bridge

INTRODUCTION

Balmoral Road Release Area (BRRA) is a previously rural agricultural area of approximately 410 hectares located in the Hills Shire Council approximately 30km from Sydney's CBD.

To cater for Sydney's ongoing growth, planning for the development of the area started in 1999 and the area was rezoned in 2005. The area will support 6,000 new dwellings and will accommodate approximately 13,000 additional residents.

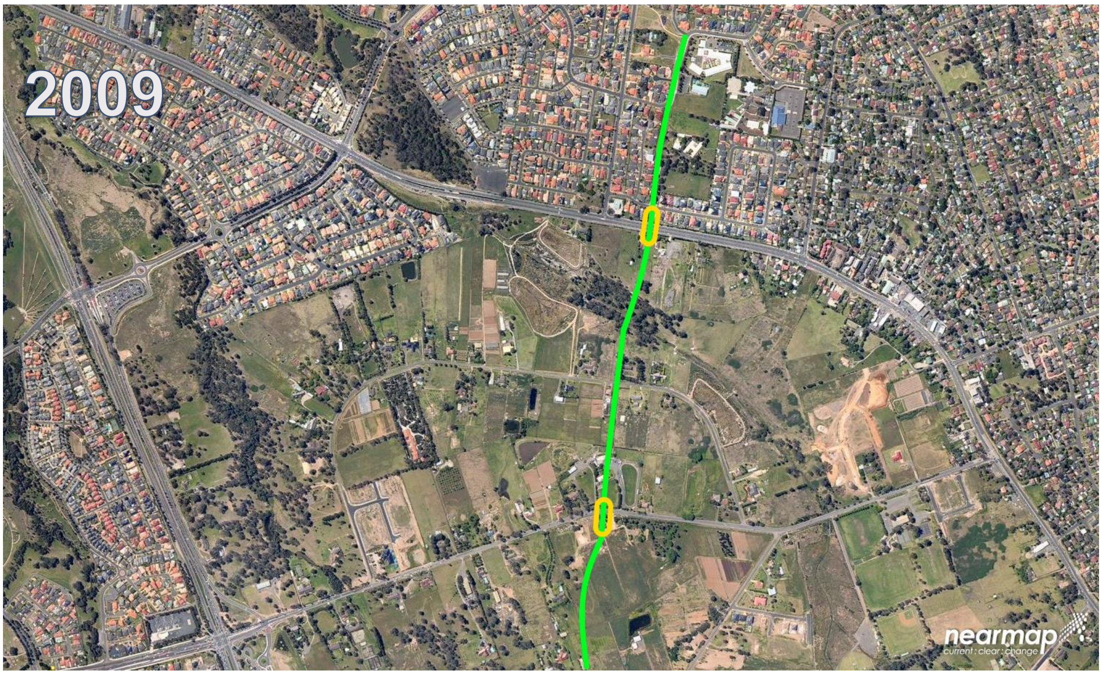

Figure 2 – BRRA Aerial Image 2009

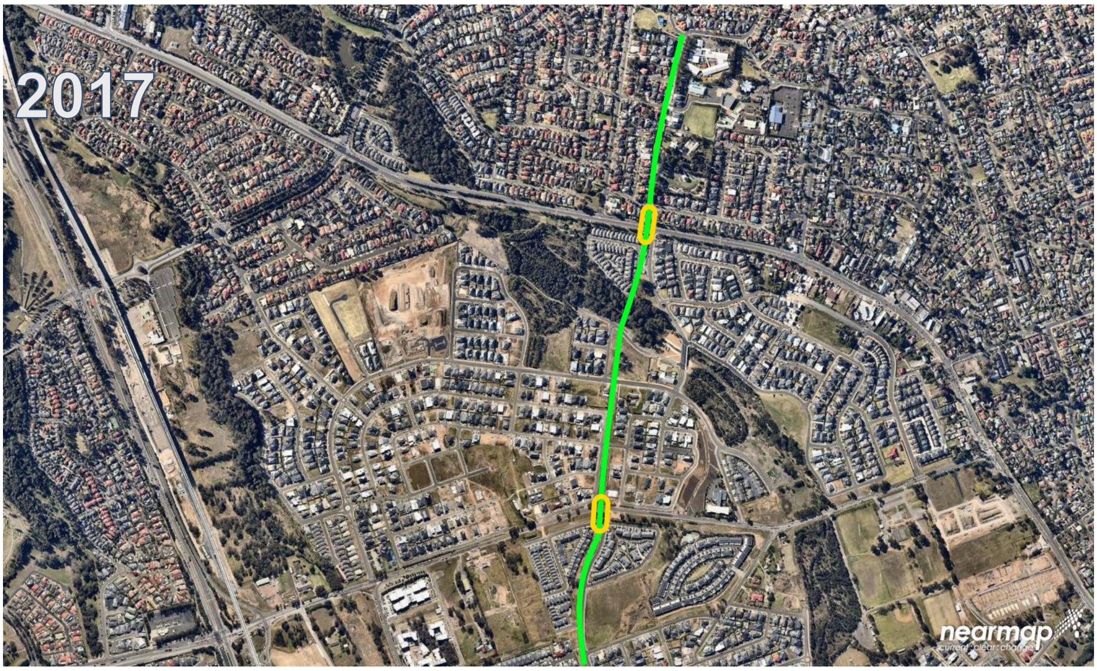

Figure 3 – BRRA Aerial Image 2017

Part of the planning for the area includes a ‘Greenway Link’ or off-road shared path for cyclists and pedestrians to promote active recreation and provide a connection between the adjacent major centres of Norwest and Rouse Hill. The two biggest obstacles in the path of the Greenway link are Windsor Road and Memorial Avenue, two major state arterial roads which are both designated high vehicle routes.

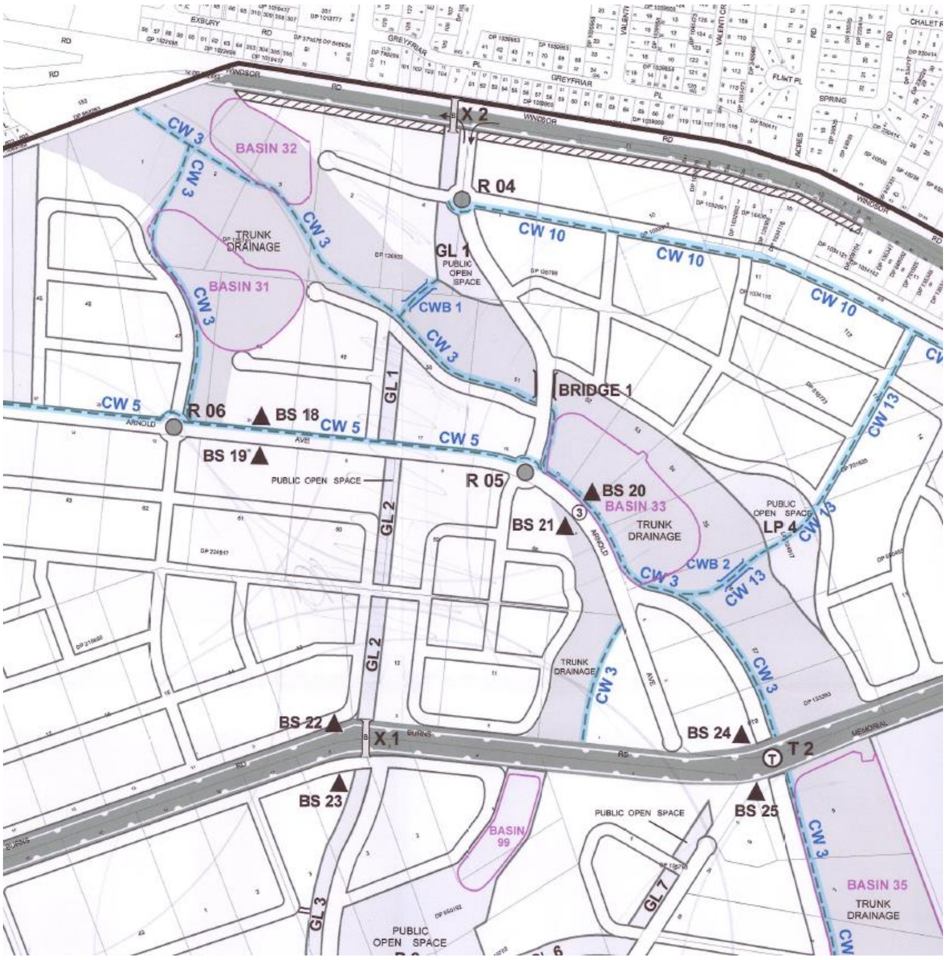

Figure 4 - Local Area Bridge Locations

Council allocated funds for design of the two bridges in 2015 and sought quotes for a structural engineer to undertake the design of both bridges as a single package. The intention was to provide consistency for the two structures.

Beca were already engaged by RMS for the detailed design of the Memorial Avenue upgrade so they were well positioned to undertake the design of the pedestrian bridges.

Most design considerations, constraints and decisions were shared between both bridges, specifics outlined in this paper will refer to the Windsor Rd bridge.

Preliminary Concept

Council brief called for the most practical, durable and economic designs for these bridges, with the following basic requirements:

- Making allowance for the upcoming widening of Memorial Avenue to four lanes and also for an ultimate six lane configuration for both Memorial and Windsor Roads
- Be appropriate for their setting including respect for the privacy and outlook of nearby residential properties.
- Exceptional durability to provide a design life of 100 years with minimum long term maintenance.
- An appealing modern aesthetic design consistent between the two bridges with consideration to road safety and safety in design principles

Council's budget for each bridge was $1.73M including internal project management costs, design, investigation, approvals and construction.

Ramps were the desired primary access method in keeping with the cycling focus.

It was identified early in councils investigations that due to topography of the surrounding natural terrain AS1428 compliance was going to be impossible without very long approach ramps.

This quick sketch from July 2015 from Council's archives examines the feasibility of AS1428 compliance and indicated that the required ramps just wouldn't fit in the available space.

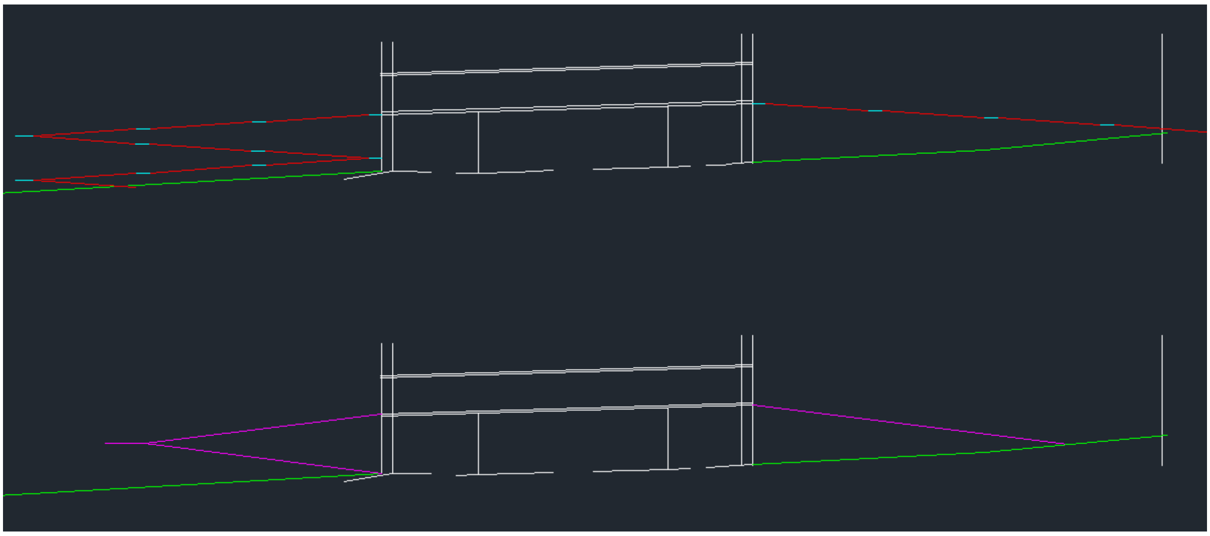

Figure 5 - Early 2D Feasibility Sketch

Councils early concept designs were as follows

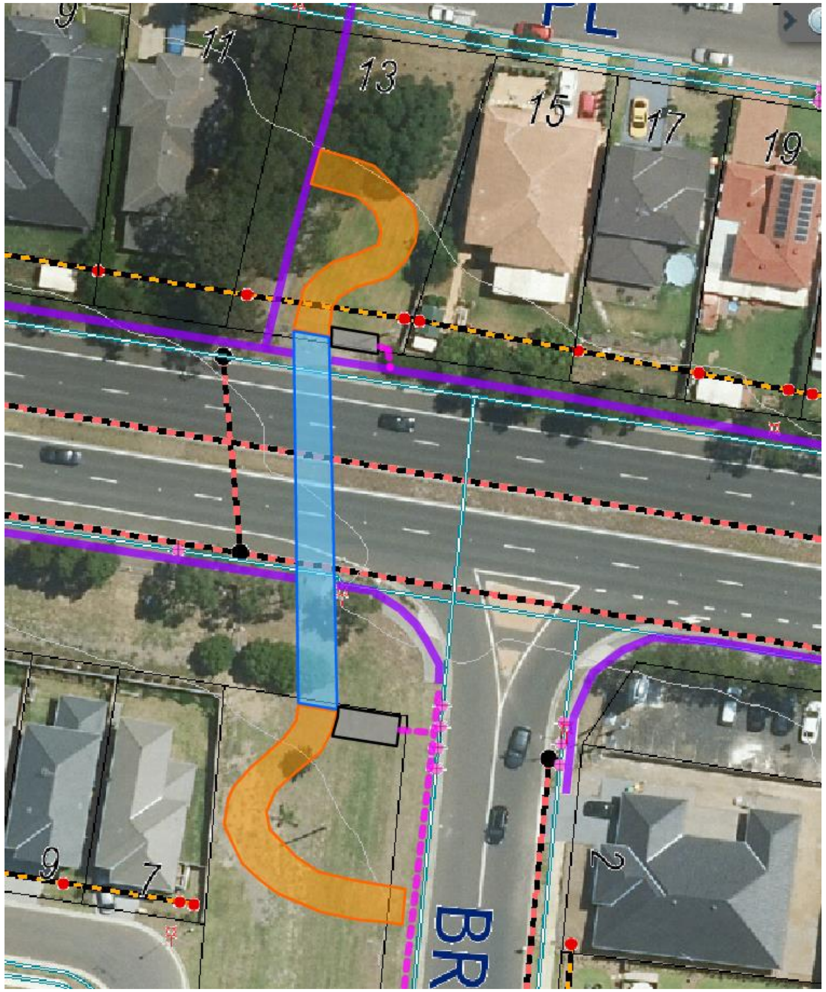

Figure 6 - Council Preliminary Concept Windsor Rd

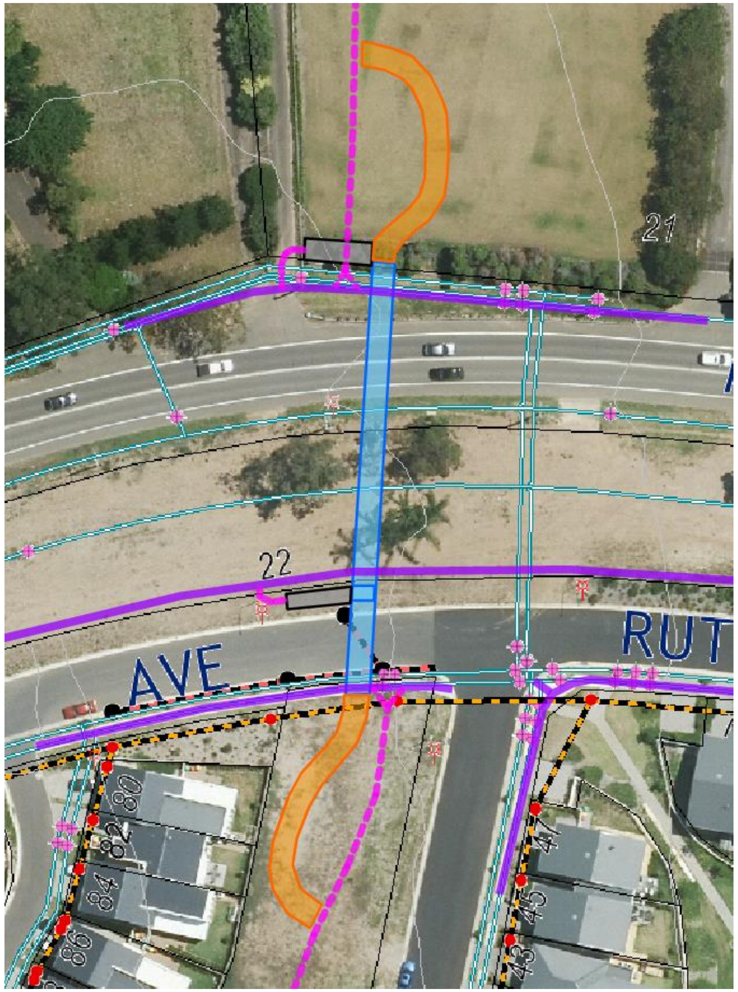

Figure 7 - Council Preliminary Concept Memorial Ave

Design Philosophy

The following design constraints drove the design to take its structural form aesthetically and geometrically.

- North and south approach ramp with minimal width restricted by adjacent road and property boundaries.
- Site sloping from North to South
- Minimum 6m clearance over Main Road including an allowance for future widening
- No piers or abutments to be within the RMS road reserve requiring a large unsupported span of approximately 45m & 50m for Windsor Rd & Memorial Avenue respectively

Upon investigating a number of different structural forms and geometries it became clear that one of the biggest design drivers was going to be the approach ramp geometries. With the sloping sites and a maximum ramp slope or 1 in 8 specified by the client, a clever solution to minimise length of approach ramps and keep within site constraints was needed.

To achieve this, the following key geometric characteristics were requisite of the structural form:

- Low profile form over road to keep finished surface level as low as possible
- Curved finished surface level in elevation over main span
- In-plan curves on approach ramps to decrease length of footprint required for approaches

Urban Design Philosophy

The urban design was a key driver for the project to ensure that the functionality of this cycleway connection was matched with a suitable urban design philosophy for Sydney’s garden shire. The urban design had to consider the following

- Privacy for adjacent residents
- Security & safety of pedestrians on the bridge
- Lighting
- Aesthetics that match the surrounding landscape

One of the major features of the bridge is the perforated mesh which spans across the truss and on the suspended approach ramps when adjacent to property. The perforated mesh is seamless and features 3 tiers of opacity which is achieved by adjusting aperture size. The first tier below torso level provides enough transparency to provide a visual connection inwards and outwards for security. The middle tier has very little transparency to maximise privacy at eye level and the upper tier is transparent again to allow maximum visual effect and natural lighting.

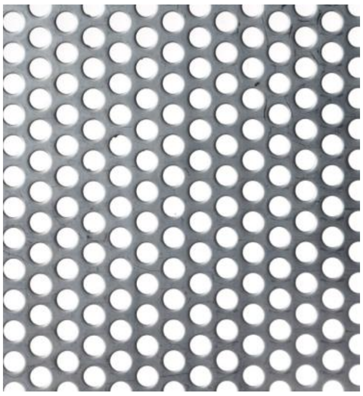

Figure 8 – Perforated Mesh

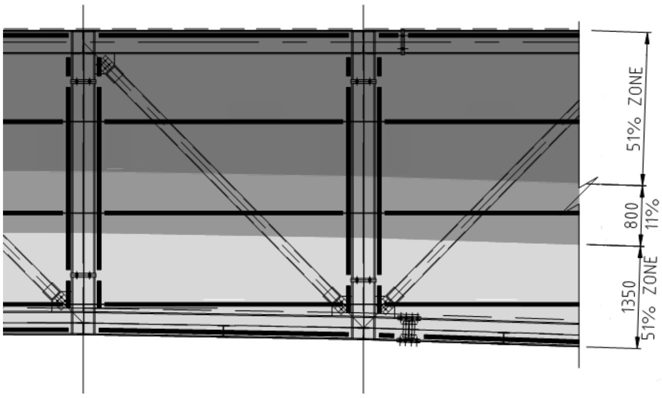

Figure 9 –Mesh Profile Elevation

Structural Design Philosophy

The structural form was decided upon to conform with the functional requirements of the site and project requirements.

<u>Main Span</u>

- Hot Dip Galvanised Steel Box Truss with curved bottom chord
- Combination of Universal Column members for chords, verticals and cross members and Rectangular Hollow sections for diagonal ties
- Reinforced concrete surface with permanent formwork

<u>Approach Ramps</u>

- Suspended in-situ RC approach ramps curving in plan with approx. 10m spans
- RC concrete slab on fill

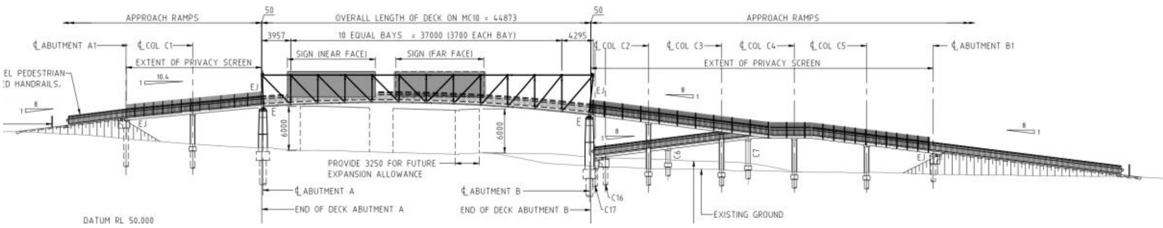

Figure 10 - Windsor Rd Bridge Elevation

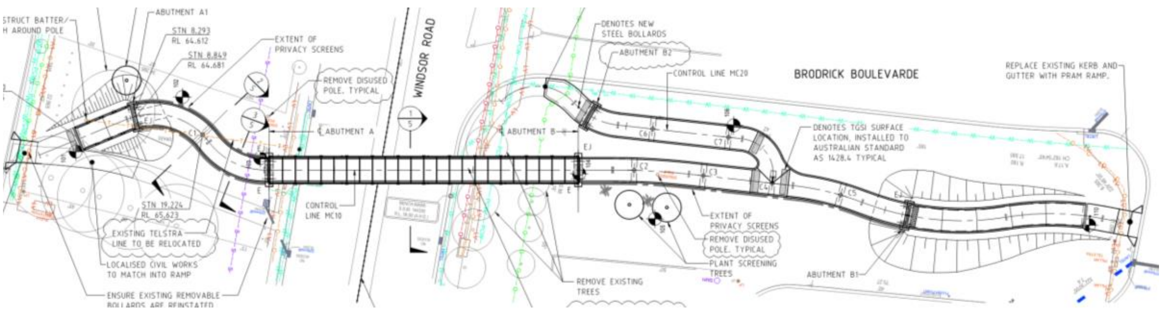

Figure 11 - Windsor Rd Bridge Plan

Structural Design Challenges – Main Span

The main span utilised a box truss structural system which was chosen for its inherently lightweight form, low profile nature and the safety benefits of having an enclosed structure.

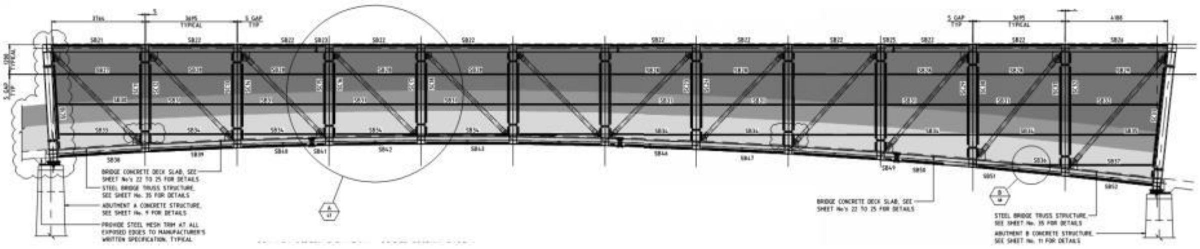

Figure 12 - Truss Elevation

An important visual element of the design is the horizontal top chord and the curved bottom chord. This presented some challenges for design and construction. The first challenge was the design of the end portals. Lateral loads taken by wind, impact and earthquake have a load path that travels along the top chord and to the supports mostly through the end portals. Despite the portals of the central bays being 3.9m wide and 3.7m high (node to node), the worst case end portal was the same width of 3.9m wide but 5.4m in height.

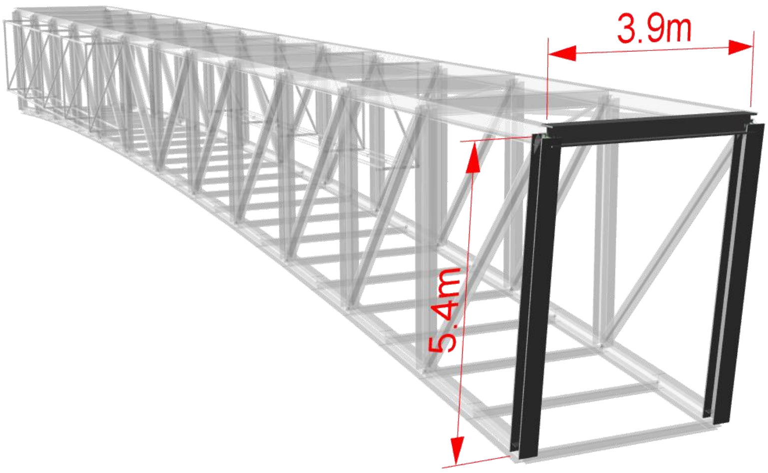

Figure 13 - End Portal Perspective

The end portals are the only elements of the truss requiring a welded column section.

The curved nature of the bottom chord also changed the traditional behaviour of a simply supported truss. As the truss is loaded, the truss behaves mostly like a simple truss but it also exhibits arch like characteristics. The design actions for the truss elements, especially for the bottom chord are sensitive to changes in support fixity in the longitudinal direction. The stiffer the support fixity, the more arch-like actions the truss begins to exhibit resulting in horizontal reaction forces in the longitudinal direction. The support fixity being a function of the bearing, the pier, piles and ground stiffnesses as well as any contribution from adjacent span, a sensitivity analysis was undertaken to analyse the expected range of element actions and bearing reactions.

Structural Design Challenges – Approach Ramps

The approach ramps are a continuous in-situ reinforced concrete ramp with columns at 10m centres. Due to the curved nature of the bridge the approach ramps were modelled using a refined grillage model as shown in figure 14 using typical grillage model theory. Modelling these elements as a grillage not only allowed for a refined analysis of actions on the deck especially torsions and dynamics but also provided refined analysis for actions on columns including temperature and shrinkage.

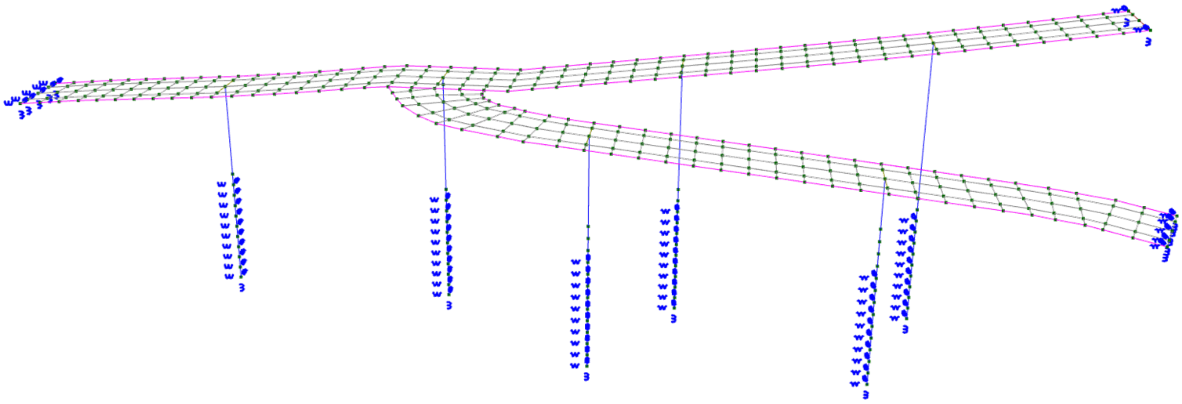

Figure 14 - Windsor Rd South Ramp Grillage Model

Structural Design Challenges – Main Truss Piers

The main truss piers are the primary supports for the main span truss as well as the end support for the approach ramps. The cantilevered arms were a key aesthetic element to be achieved with the design and as such being cantilevered and with significant loads, required special consideration structurally. The biggest challenge came in the geometry of the “palms” of the arms to fit bearings, restraint blocks and allow for jacking for bearing replacement. Jacking the truss from underneath the main bottom chords adjacent to the bearings (as would be typical) would be impossible without changing the geometry of the pier. By providing the jacking surface on top of the lateral restraint blocks keeps the jacking location within the “palm” print. Stiffening of the end portal bottom cross member to transfer this jacking load to the truss was required to accomodate the eccentricity.

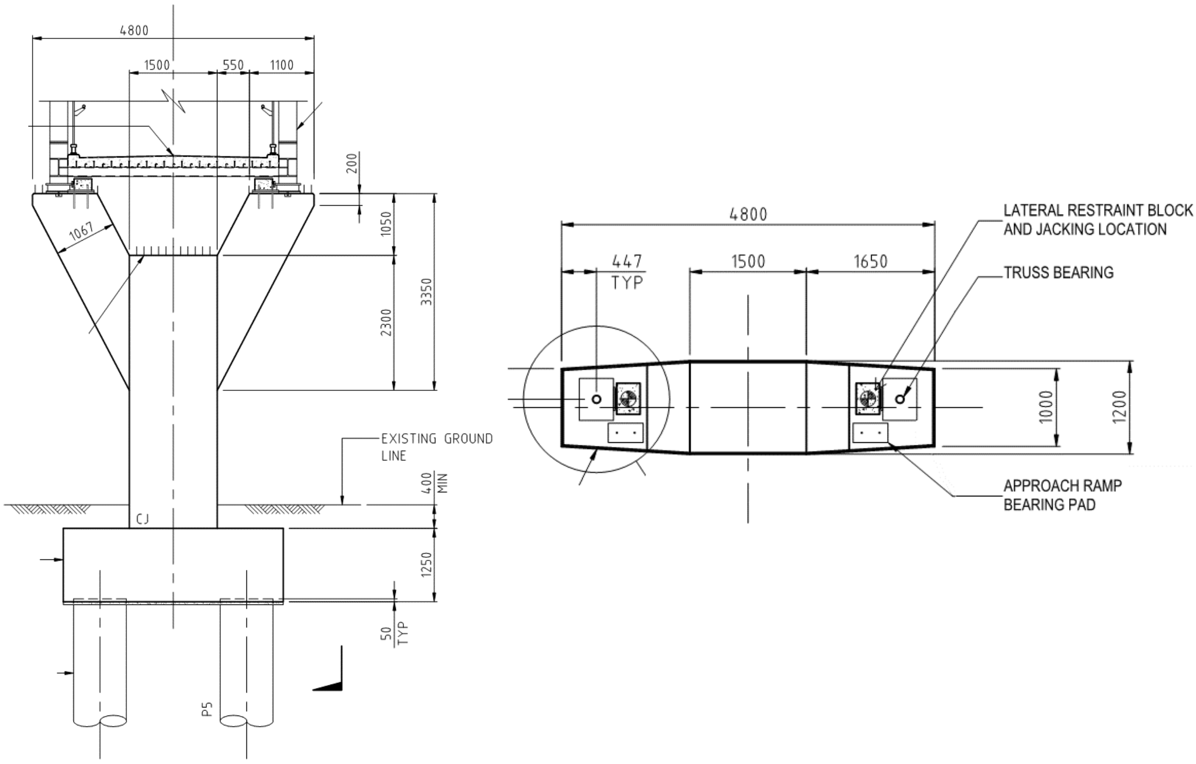

Figure 15 - Pier Elevation and Plan

Construction Phase – Procurement

Council prepared the construction tender and contract documentation. Beca provided input for the specification where design assumptions necessitated special parameters. The specification was then developed by Council as a project specific document with heavy reference to RMS QA bridgeworks specifications wherever possible.

During the construction process additional measures were put in place to ensure construction phase quality assurance, in some cases above and beyond current code requirements including:

- The requirement for the fabricator to build special test pieces from the same batch of steel used in the bridge and carry out a full suite of non-destructive and destructive testing to verify the performance of the welding procedures to be used on the project.
- Very careful specification of the degree of non-destructive weld testing required including categorisation and tabulation of every weld on the structure and specification of the proportion of Visual, MPE and ultrasonic testing required.
- Incorporation of the newly released standard for high strength structural bolt assemblies AS1252:2016. This requires a more rigorous degree of compliance testing of the bolts, nuts and washers including testing as a complete assembly.
- The requirement to complete a trial assembly once welding was complete but prior to galvanising and painting to avoid any assembly issues on site.

Council called open public tenders for construction of the bridge using an AS4000 based contract and received 6 submissions. The accepted contract sum from Delaney Civil Pty Ltd was approx. $2.5M.

Construction – Windsor Rd

Construction commenced in May 2017 and due to a particularly dry winter, construction has had very few delays.

The approach ramps were completed in October 2017 and at the time of writing, the main truss is being bolted together on site for installation before the end of the year.

The installation of the truss will require a full closure of the busy Windsor Road over several night shifts to lift the truss into place and then to pour the in-situ concrete deck.

It is hoped that the bridge will be open for pedestrians by the holiday period at the end of the year.

Remote monitoring cameras have been in place throughout construction to monitor progress.

CONCLUSION

The two pedestrian bridges in Kellyville will provide the missing links for the greenway link shared path connecting Norwest and Rouse Hill in Sydneys north-west. The team of Urban Designers, Engineers and Council achieved an aesthetic, robust and sustainable design that allowed for future expansion of the road network and minimal impact to nearby residents. Rigorous quality control during construction ensured a high quality of workmanship conforming to the latest codes and quality standards. The final form of the bridge structure is a result of functional requirements driving a flowing geometry and structural form that provide two iconic portals to Sydney's garden shire.

AUTHOR BIOGRAPHIES

Ryan Dewar

Ryan is a Civil Structural Engineer with experience in a range of different projects in the Infrastructure market providing structural analysis and design of structures. He is a graduate of the University of Queensland with 1st class honours studying a Dual Degree in Civil/Structural Engineering and Commerce (Finance). Ryan also has a range of construction Site Engineering experience in projects which include Road, Airport, Hospital and Plant & Animal facilities.

David Duffield

David is a civil structural engineer and project manager responsible for delivering new infrastructure projects for The Hills Shire Council. David has a bachelor's degree in civil engineering from Wollongong University and a Masters of Engineering Science in Project Management from UNSW@ADFA. David's experience includes time in the design office as a consulting engineer and time on the construction site as superintendent's representative. David has been involved in projects on the M5 motorway in Sydney, Gungahlin Drive in Canberra, structural analysis and design for Sydney Water assets and delivery of road, building, waterway and bridge projects for The Hills Shire Council in suburban Sydney. David's passion is managing the design and construction of road and pedestrian bridges.