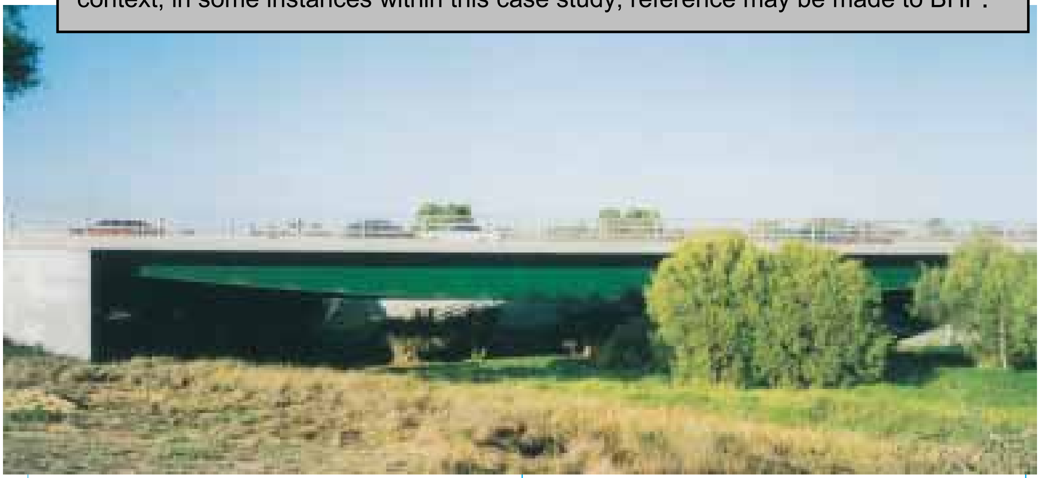
This case study was written at the time when OneSteel was part of BHP. In that context, in some instances within this case study, reference may be made to BHP.

Steel Spans Sacred Site



The site spanned by a recently constructed bridge over Bennett Brook, some ten kilometres north of Perth, Western Australia, has special significance to the local Aboriginal people. It is the home to the Wagyl, a mythical serpent that lives in valleys, under creeks and rivers. Its sacred site status meant that the ground within a 52 metre wide strip along the valley could not be penetrated or worked on, with only pedestrian entry allowed during construction.

The challenge facing designers Bruechle, Gilchrist and Evans, was to design a bridge that could be constructed economically from beyond this exclusion zone. To further complicate the task, the road alignment combined horizontal and vertical curves with deck superelevation and a 49 degree skew. In addition, the bridge was placed on ‘fast track’ because it had the potential to delay the completion of the overall project. To ensure minimum delay to construction, most of the materials were ordered before completion of the final design – further adding to the risk and complexity of the overall project.

The chosen solution was a composite steel superstructure spanning 56 metres. The bridge deck is 20 metres wide and comprises six fabricated I-Beams with a shallow inverted arch-shaped profile. This profile, also known as a ‘fish belly’, was chosen for its architectural and practical reasons to fit the small valley shape. The abutments are not parallel because of the combination of curvature and skew and this required beams of slightly varying lengths. The abutments were built to accommodate the planned final duplication of this bridge in the future.

Construction of the bridge under these difficult constraints stretched the engineering skills of the designers and led to a number of clever innovations in both design and construction.

Design

The detailed design of this bridge required close scrutiny at every stage of fabrication, transportation and site construction. Particular attention was given at the deck casting stage due to the effect of the high skew on the stability of the beams and seating of the precast decking on the top flange. Joe Wyche, Gilchrist and Evans’ design leader said, “The large span and the shape of the girders called for the use of triangulated horizontal bracing to stabilise the compression flange during the construction stage”. This comprised circular hollow sections (140 CHS to 220 CHS near the ends). The connection details used for these large braces kept them close to the critical compression flange and allowed placement of the ‘Transfloor’ panels immediately above them. They also accommodated the differential deflections between adjacent beams during deck construction through their low vertical stiffness. The ends of the girders were stabilised torsionally with an 800 WB used as a diaphragm.

The bridge was designed for HLP 400 AUSTROADS Heavy Load Platform for both the initial and final, duplicated bridge stages. The beams’ depth varies between 1000 at the ends to 2300 mm at midspan. The top flange is a constant 32 x 580 mm. The 32 mm thick bottom flange varies in width for beam pairs from 780 to 880 mm. The web thickness varies from 16 mm at midspan to 25 mm at the ends. All steel is Grade 350.

Fabrication and Transport

The fabricator chose to fabricate the beams in the workshop and transport them to the site in pairs on a steerable jinker. To facilitate fabrication the same inverted shallow arch shape was used for all webs with the length variations being accommodated by varying the straight end segment lengths. This meant that the same jig set-up could be used for all beams with obvious time and cost savings.

The flange to web welds were originally specified as 8 mm fillet welds increasing to 10 mm for part of the beam length. The fabricator, Kewdale Structural Engineering, suggested an alternative partial penetration butt weld (without any additional plate preparation) using an automatic welding machine at no additional cost. The designers agreed to the change and were very happy with the end result.

Erection

Several methods of installing the beams were considered including launching and erection of either single or braced pairs of beams. The chosen method was placement of braced pairs by crane because it was considered the most predictable and safest. A 350 tonne crawler crane was used on a 35 metre lifting radius to install the almost 100 tonne weight of the pair of beams. This meticulously planned lifting operation resulted in fast, trouble-free erection despite the difficult constraints. This highlights the advantage of steel’s relative lightness to facilitate construction over large spans.

Transfloor Decking

‘Transfloor’ decking, precast in 95 mm thick and 2500 mm wide sections was used to form the deck. This proved a convenient solution

because there would have been no practical access to install or remove falsework or formwork. The decking spans 3390 mm between the girders along the skew with lateral cantilevers of up to 1600 mm. It was then placed by crane in three segments, each continuous across two steel girders to provide an instant safe working platform.

Consideration had to be given to the behaviour of the 'Transfloor' during casting of the in-situ concrete topping slab to cater for large differential deflections of the adjacent girders.

Joe Wyche said, "The relative deflection differentials, due to the offsetting effect of skew, were calculated to be between 20 and 50 mm along the beam. The decking was designed to be strong enough to overcome the resulting uneven seating and support this would cause during casting. Joints were sealed to prevent any grout leakage. This worked well in practice and the final appearance is very good".

Shear Studs

Shear studs were flash welded on site after placement of the precast decking. This allowed easy placement between the reinforcing steel protruding from the panels and was done quickly and economically.

Deck Concrete Placement

A 155 mm topping was cast to complete the deck slab in a manner which minimised the effect of differential beam deflections during casting. To ensure that deflections occurred as predicted, a special pattern of concrete placement was devised. This comprised commencement at mid-span with a strip of concrete placed along the skew over the entire deck width. Placement of concrete then proceeded parallel to this front in both directions from the centre of the bridge towards the abutments.

Bearings

The large beam deflections during casting also caused large rotation at the ends of the beams. In order to minimise the size of the bearings, the contractor chose to place the beams on temporary sand jacks which allowed the rotations to occur under dead-load. The completed composite structure was then lowered onto permanent circular elastomeric bearings, 650 mm diameter and 224 mm high, which were designed for live load rotations only.

Conclusion

Construction of this steel bridge provided substantial challenges for both designers and contractors, along with site access restrictions which were observed in accordance to Aboriginal tradition.

The project is an excellent example of a modern composite steel bridge system used to provide a unique bridging solution for a long span bridge with access restriction. Construction was made safe and easy despite the difficult site constraints by clever engineering combined with a precast deck formwork system allowing all site work to be done from the top of the bridge. The availability of a large capacity crane and transport enabled these long beams to be fabricated and coated entirely in the workshop saving valuable time and costs. The end result is a cost effective bridge with appealing aesthetics.

Project participants:

Client and Project Superintendent:	Main Roads, Western Australia
Designer:	Bruchle Gilchrist & Evans
Main Contractor:	Barclay Mowlem Construction
Project Manager:	Highway Construction
Fabricator & Transporter:	Kewdale Structural Engineering
Transfloor Designer & Fabricator:	John Holland Construction & Engineering

Opposite, top: The 56 metre span leaves an Aboriginal sacred site undisturbed.

Far left: Lifting a 100 tonne braced pair of beams into position.

left: Placing the precast decking.