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.

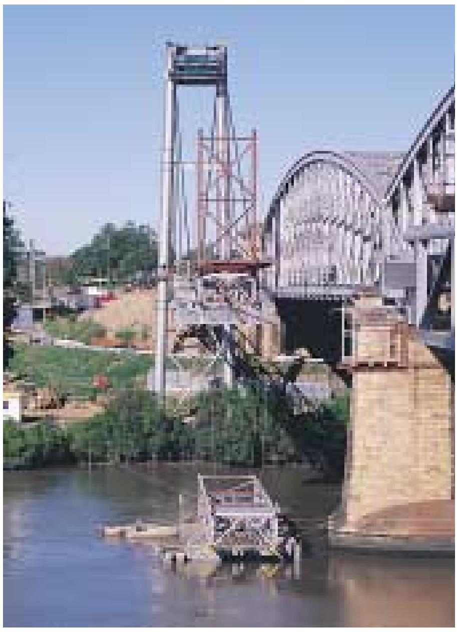
Cable-stayed steel bridge wins awards

This new steel truss bridge provides an elegant clear span and low cost solution to a new Brisbane River crossing.

The Jack Pesch Bicycle and Pedestrian Bridge is a three span cable-stayed structure providing access across the Brisbane River between Indooroopilly on the north bank and Chelmer on the south bank. The Queensland Department of Main Roads and the Brisbane City Council jointly funded the project, which is an important link in the developing network of bikeways throughout Brisbane. Moggill Constructions Pty Ltd successfully tendered the bridge on a design and construct basis, to a design by Kinhill Pty Ltd.

It is the longest span cable-stayed bridge in Queensland and has recently won a High Commendation Award in The Institution of Engineers, Australia (Queensland Division) Engineering Excellence Awards, and the Australian Institute of Steel Construction, Structural Engineering Steel Design Awards. The awards judges were particularly impressed with:

- The fact that the contract was won in a competitive environment with an alternative design
- A more efficient use of structural steel was achieved by using a 2m deep truss instead of the proposed plate girders in the conforming design
- The depth of analysis undertaken by the engineers to ensure pedestrian comfort (utilising time dependent analysis techniques)
- The innovation demonstrated by eliminating the central pier and, despite doubling the span, being able to offer a net saving over the conforming design



Left: Construction of the new bridge adjacent to the Heritage Listed Albert Bridge.

Above: The completed Jack Pesch Bridge.

The bridge is located immediately downstream of two rail bridges and a road bridge, all of which are Heritage Listed. The design therefore required Heritage Council approval. The bridge was commissioned on 2 October, 1998.

Design:

The bridge includes two 41m high towers, located on opposite banks of the river, and has a 4m wide carriageway. Each tower is composed of twin 1.2m diameter steel tube columns which are braced together. The tower tops are anchored to the underlying rock with permanent rock anchors. The bridge deck is supported, at 19m intervals, from the top of the towers by a plane of cables along each side of the deck. The deck level is at RL 18.386 and the deck has a navigable clearance of 13m.

The cable support system is a multi-strand system comprising polyethylene sheathed multi-strand 15.2mm diameter strands, all enclosed in a high density polyethylene protective casing.

The concrete deck is supported by, and acts compositely with, two fully welded steel trusses, 2m deep and spaced 3.9m apart. The composite action is utilised in order to carry both deck bending actions and the horizontal thrust component of the cable stays. The trusses are made from Grade 350 RHS sections. The deck consists of precast concrete deck slabs in 2.5m widths spanning between the two trusses, and made composite with the truss top chords through a continuous insitu concrete slab extension, cast outside those slabs. The slabs vary in thickness from 200mm at the centre-line of the bridge to 170mm at the interface with the insitu kerb. The handrails and bridge lighting are supported from this slab extension.

All steel reinforcement was supplied by OneSteel (formerly BHP Reinforcing Products).

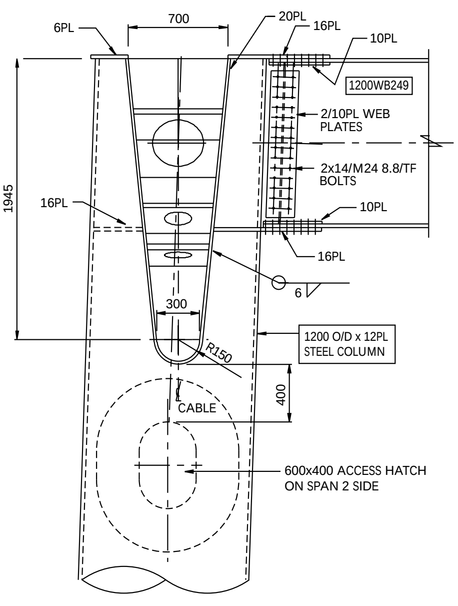
Design Criteria:

- Australian Bridge Design Code
- Live Load 5kPa uniform, or a two-axle maintenance vehicle with 50kN per axle.
- Design Wind Speed in accordance with AS1170.2, Terrain Category 2.
- Design Water Velocity 3.5m / s at RL 8.300
- Design Debris Force 250kN at RL 8.300

Design and Construct Features:

Moggill Constructions Pty Ltd, as well as offering a conforming tender for $3.24m, also offered an alternative design prepared by consulting engineers Kinhill Pty Ltd, for $2.73m. The alternative design was accepted by the client. The successful alternative is a three span cable-stayed structure with a central span of 167m completely spanning the river, thereby avoiding the need to contruct two piers in the river, as detailed in the conforming design.

Pier 1 top connection



Truss segment on barge prior to lifting.

According to Kinhill Principal Structural Engineer, Ken Ross, the high strength-to-weight ratio of structural steel and the relatively light loads to be supported made steel the obvious design choice. The alternative design, utilising steel trusses, provided the following benefits:

- Improved dynamic performance
- Avoidance of river piers (vulnerable to impact from 3000 tonne coal and gravel barges)
- Simplified construction
- Significantly lower cost
- Improved aesthetics

Dynamic Performance:

The most critical aspect of a relatively light pedestrian bridge is its dynamic performance, which needs to ensure the comfort of the pedestrians, and allay concerns about the safety of the bridge. Kinhill supplemented the limited guidance provided by the Australian Bridge Code (viz. max dynamic deflection of 6mm for modes between 0.5Hz and 1.0Hz) and the Australian Wind Code.

A three-dimensional modal analysis was carried out and the lowest seven modes of vibration examined. The fundamental frequency of the structure is 0.7Hz, with frequency of higher modes increasing up to 1.9Hz at the seventh mode. Kinhill compared the bridge's dynamic performance with limits recommended by A.W. Irwin in a paper 'Human Response to Dynamic Motion of Structures', in The Structural Engineer (No. 9, 1978). The paper proposes human comfort limits for both vertical and horizontal motion over the frequency spectrum up to 5Hz.

The bridge design comfortably met Irwin's criteria for vertical motion for all time-dependent vertical load functions. Under wind load, where the lateral accelerations increase as the wind speed increases, Irwin's suggested criteria was reached at a gust wind speed of 25m / s, where the peak acceleration of the bridge deck is 0.4m / s^2. By comparison, the calculated peak acceleration on the conforming design at this wind speed was approximately twice as high.

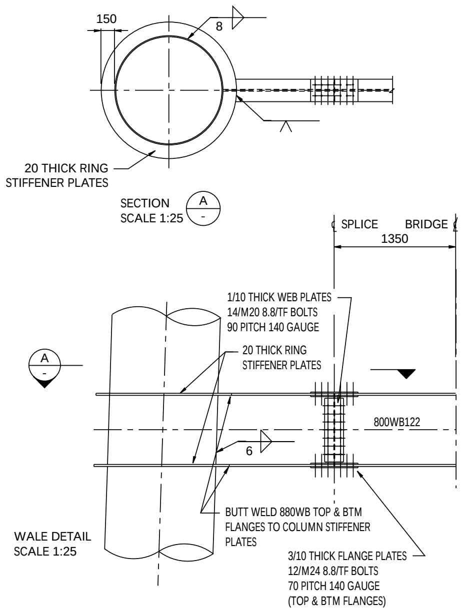
Construction:

Frank Sturley, Project Manager for Moggill Constructions, believes that the steel structure contributed greatly to the success of the construction process. By being able to erect 10tonne deck truss segments using a lightweight lifting frame, and secure each truss segment in turn with cables, a simple method of constructing the bridge deck was ensured.

The detailed construction sequence was as follows:

1. Construct Chelmer abutment and erect Chelmer tower, including temporary stay to the adjacent bank

Wale detail and section



Tower and deck with lifting frame.

2. Erect Chelmer approach span so as to longitudinally brace the tower back to the abutment; erect cables; remove temporary stay. Erect Indooroopilly tower, with temporary stay to bank.
3. Wheel the travelling lifting frame along the deck from the Chelmer bank; lift first 19m cantilevered truss section from a barge, utilising a heavy duty tow truck winch with the tow truck located at the Chelmer embankment. Erect Indooroopilly approach span.
4. Progressively add 19m truss sections by winching up from the barge and cantilevering out from the previous deck section. Support cantilever ends of truss sections by initial cable strands.
5. Transfer travelling frame to Indooroopilly side, wheel into position and lift the first cantilevered truss section from the barge.
6. Progressively add truss sections to the Indooroopilly side, finishing with the closing centre section (Note that at the expansion (Chelmer) end of the bridge, the deck had been temporarily preset so that the closure gap was oversize). Once the closure truss was lifted between the two opposing cantilevered deck ends, the preset was released and the Chelmer deck jacked towards the Indooroopilly deck so that the closure could be butt welded.
7. Erect precast concrete deck units, spanning between the two trusses. Cast insitu concrete kerbs outside the slabs and add deck furniture.

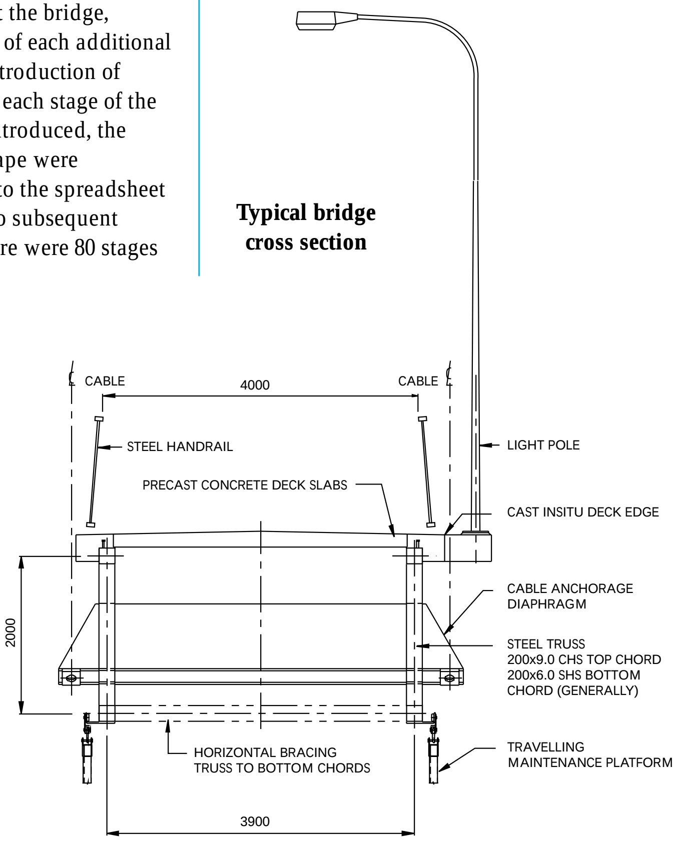
To achieve the successful erection outcome, each stage of the bridge erection was structurally analysed to determine the cable forces and deflected profiles resulting from that stage. When each strand was introduced to the cable, it needed to be locked into the structure with such an elongation that when all the dead load was eventually applied to the structure, a level (or slightly cambered) deck profile was achieved. This was further complicated by the need to ensure each strand in the cables always carried a minimum positive tension of 15kN, so as to minimise the risk of strand wedges becoming loose. This meant that strands could only be introduced into each cable concurrently with weight being added to the deck that the cables were supporting. Also, each strand was not permitted to exceed 100kN at any time.

Consequently, a detailed construction procedure was documented in spreadsheet form, which identified at each stage the cable forces and deflected profile at the bridge, arising from the introduction of each additional truss section, and from the introduction of strands into each cable. After each stage of the erection where cables were introduced, the cable forces and deflected shape were measured on site, compared to the spreadsheet data, and adjustment made to subsequent stages as necessary. In all, there were 80 stages of erection.

Tower and deck during construction.

Final truss segment being hoisted into place.

Typical bridge cross section



A design decision involved a trade-off between increasing the size of the truss top chord to withstand the compressive forces compared with resisting the compressive forces through the deck. The decision to resist compression through the deck meant that, once placement of the precast panels had been completed for a 19m section, the insitu concrete kerb had to be poured and cured before any further precast decking units could be placed. The 4.5 tonne precast panels were placed using a 6 tonne Franna mini crane which walked over the newly laid panels.

Fabrication:

Sun Engineering Pty Ltd fabricated the fourteen truss sections, each 19m long, and the two tower frames in their workshop at Carole Park. Particular challenges that were overcome by Sun Engineering include:

- Fabrication of the truss segments to achieve site fit
- Three-dimensional assembly of the tower heads

In order for the bridge deck to be level when complete, the deck trusses needed to be fabricated in the shop with an upward camber. The camber followed an approximately sinusoidal curve having a maximum 705mm high displacement at midspan. The camber was imparted to the deck in a series of angle changes at the splices where the fourteen straight truss segments abut each other. To achieve fit at the splice, the four main chords of the truss had to be aligned to within 3mm in the three orthogonal directions. This was achieved by jigging of the trusses.

Since the tower legs are inclined to the plane of the cables, the setout of the tower head and cable anchorages had to be accomplished in three dimensions. This was achieved through sequential assembly of the components.

The accuracy of fabrication, and in particular the successful cambering of deck trusses and accurate fabrication of the tower heads and cable anchorages, ensured that only very minor rectification work was required during site assembly.

Truss segments about to be spliced.

Shear studs were shop welded to the truss top chords and consist of 16mm diameter x 100mm double studs at 350mm centres generally, and 150mm centres for a distance 1600mm each side of each cable connection point. The weight of steel in the deck is 138 tonnes, and in the tower frames 92 tonnes. Total steel weight is 230 tonnes.

The top of both tower frames is 22m above deck level, and the column centre-lines are 4.9m apart at the top. The top of the Chelmer pier frame is 38m above pile cap level, whilst the top of the Indooroopilly pier frame is 33m above pile cap level.

Protective Coating:

The towers were originally designed to be hot dipped galvanised, however Moggill Constructions utilised a paint system ('St Enoch's Grey') for the whole bridge. The system was approved by the Heritage Council and matched the existing adjacent bridges.

Project Success Factors:

- Ease of handling and lifting of lightweight steel trusses, which were delivered to site in 19m long prefabricated assemblies, moved into lifting position by barge, and erected by a lightweight lifting frame on the bridge deck
- Aesthetic new addition to complement three historical steel bridges
- Avoidance of river piers
- Fast, safe construction technique
- Composite construction providing twin design benefits of deck structure bending strength and compression
- Lower cost
- Improved dynamic performance

Client:	The Queensland Department of Main Roads and the Brisbane City Council
Structural Engineer:	Kinhill Pty Ltd
Design & Construct Contractor:	Moggill Constructions Pty Ltd
Steel Fabricator:	Sun Engineering
Stud Welding:	Stud Welding International
Shop Drawings:	G & D Drafting