LSAA
LIGHTWEIGHT STRUCTURES ASSOCIATION OF AUSTRALASIA

Project Name: **Jim Stynes Bridge**

Location (Street Address): **cnr Harbour Esplanade and McCrae Street, Docklands, Victoria**

City: **Melbourne** State: **Victoria** Country: **Australia** Postcode: **3008**

GPS Location (if known) **Latitude**: -37.822919° | **Longitude**: 144.947858° Completion Date: **18 June 2014**

Preferred Category (**2: Medium structures**) Alternate Category (N/A)

Entrant Name: **Aurecon**

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Entrant Type / Role (Designer / Engineer / Architect / Fabricator / Installer / Other): **Engineer**

Project Client: **State Government of Victoria and City of Melbourne**

Project Architect: **Cox Architects**

Structural Engineer: **Aurecon**

Specialist Consultant & Role: **Oculus** – Landscape architect and urban design
Cox Architects – Urban design

Other Consultants & Role: **Electrolight** – Specialist lighting
Architecture & Access – DDA consultant
RPS Project Management – Project management
Aurecon – Electrical engineer, survey, geotechnical engineer, planning, project management

Building Contractor: **Fitzgerald Constructions** Fabricator(s): **Fitzgerald Constructions**
Focus Engineering

Others: N/A

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PROJECT NAME: Jim Stynes Bridge

APPLICATION OF PROJECT:

The Jim Stynes Bridge is a shared pedestrian and cycle path over the north side of the Yarra River, Melbourne. The innovative structure utilises tensioned steel elements to form the lightweight underpass, providing a safe link between Melbourne's CBD and two of the city's significant precincts: Docklands and Southbank.

PROJECT DESCRIPTION:

The City of Melbourne and the Victorian State Government initially commissioned a design competition to propose ideas for a safer link between the Melbourne CBD and two of the city's significant precincts, Docklands and Southbank, where the six-lane Charles Grimes road bridge formed a physical barrier.

The winning design is an exhilarating, horizontal catenary structure supporting a shared pedestrian and cycle path alongside the north bank of the Yarra River. It is a striking 125 metre-long, lightweight structure suspended over the Yarra River and sweeping beneath the road bridge, giving the impression of hovering over the water.

The design approach was one of absolute lightness – nothing more, nothing less – forming a solution that understands the fundamental requirements of context and function. The bridge's arc provides a smooth transition for cyclists, while allowing the structure to act in tension as a horizontal suspension bridge. The project provides spaces of transition and connection, and occupiable spaces of reflection and repose. A series of deliberate vantage points create a unique experience of the water's edge for Melbourne's commuters, residents and visitors.

The structural engineering solution is an Australian first. Its unique, horizontal, self-tensioned catenary incorporates the truss in its design to resist the rotating force induced by the cantilevered deck and the curved truss.

The success of the project, as evidenced by the high accolades from the client team, can be attributed to the high level of collaboration between the entire team, from client through to the contractor, to develop and construct the unique concept of this underpass.

The final result celebrates the use of exposed slender structural elements carefully integrated into the architectural and functional design that will be a lasting legacy for Melbourne's urban environment and a fitting tribute to the late, great footballer, Jim Stynes.

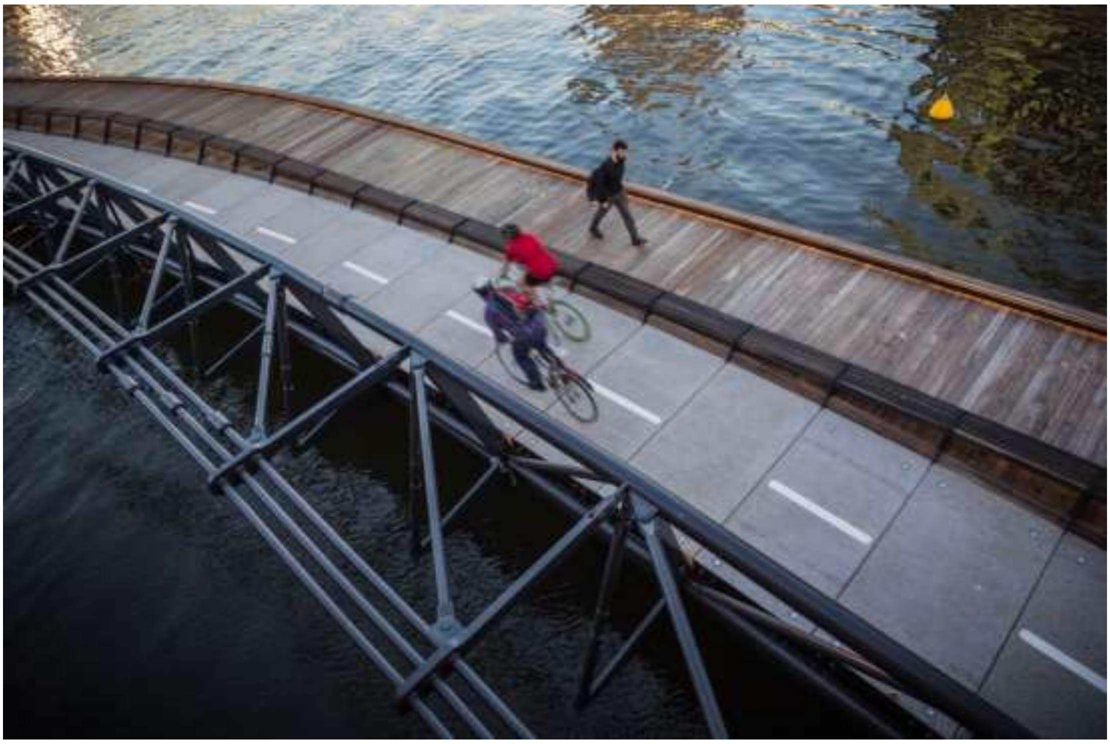


Photo by Cox Architecture

DESIGN / FABRICATION / INSTALLATION BRIEF

The concept for the Jim Stynes Bridge was spawned in a design competition commissioned by City of Melbourne and the State Government of Victoria that sought an innovative solution for connecting two city sectors, obstructed by a major six-lane highway and the Charles Grimes road bridge.

Urban context | Photo by John Gollings

The winning design epitomises the synergistic outcome achievable through successful collaboration between engineering, architecture and landscape practices. The solution is a striking 125 metre-long, lightweight structure suspended over the Yarra River and sweeping beneath the road bridge, giving the impression of hovering over the water. The final result is a sustainable and practical combination of architectural and functional design.

Client brief
As part of the client's "Linking Docklands" plan to connect Docklands to the CBD along the north bank of the Yarra River, the last piece was the connection across Wurundjeri Way, a six-lane highway. A new underpass was needed.

The winning design's success was attributed to meeting all elements of the client brief, with greater than expected outcomes from an urban design and public experience perspective:

- Safely transitions pedestrians and cyclists from one side of the overhead highway to the other;
- Smooth transition for cyclists from land, to bridge, and back to land again;
- Excellent universal access for the mobility impaired;
- All stakeholder requirements satisfied (ParksVic, Melbourne Water, Bicycle Victoria, Places Victoria);
- Unobstructed views along the river;
- Landscaped areas for recreation;
- Economical to construct;
- Durable and low maintenance;
- Minimal effect on river level during flood events;
- Lowest part of the bridge is above the 1 in 10 year river flood level;
- Adequate headroom to the road bridge above; and
- Vibration levels kept to within acceptable limits.

In action | Photo by Cox Architecture

Urban design

The Jim Stynes Bridge adds to the urban infrastructure; both as a superbly functional amenity and a magnificent tribute to one of Melbourne's heroes. The intriguing new bridge embraces the engineering constraints and challenges, cleverly using them to its advantage with a result that benefits the local community in a beautifully designed structure.

An inviting pathway, the bridge creates a much safer and amenable link to and from Docklands; it encourages people to run, walk, cycle as part of their everyday life; it takes pedestrians and cyclists away from the six-lane highway above, offering an opportunity as often expressed by Jim Stynes, to experience a personal journey.

The bridge links newly developed outdoor spaces and park areas that encourage local residents and visitors to explore the Yarra River north bank. In this way, it anticipates and will be a striking conduit to the future development of the old goods shed.

By utilising old bridge remnants for its support, the Jim Stynes Bridge has recycled a forgotten piece of infrastructure, providing economic advantages and a reduction in materials used in construction.

A world-class outcome

The Jim Stynes Bridge is a silent achiever: its structural concept is unique in Australia and stands proudly among only a few in the world. It pushed the boundaries in many ways and demanded the highest quality materials and workmanship to bring it to life.

Jim Stynes Bridge | Photo by John Gollings

STRUCTURAL SYSTEMS

The unique structural solution for realising the Jim Stynes Bridge concept was to design a horizontal, self-tensioned catenary that incorporates a truss in its design to resist the force induced by the cantilevered deck and curved truss. The end result may seem elegantly simple, but significant structural gymnastics were required to fulfil all of the functional and spatial requirements:

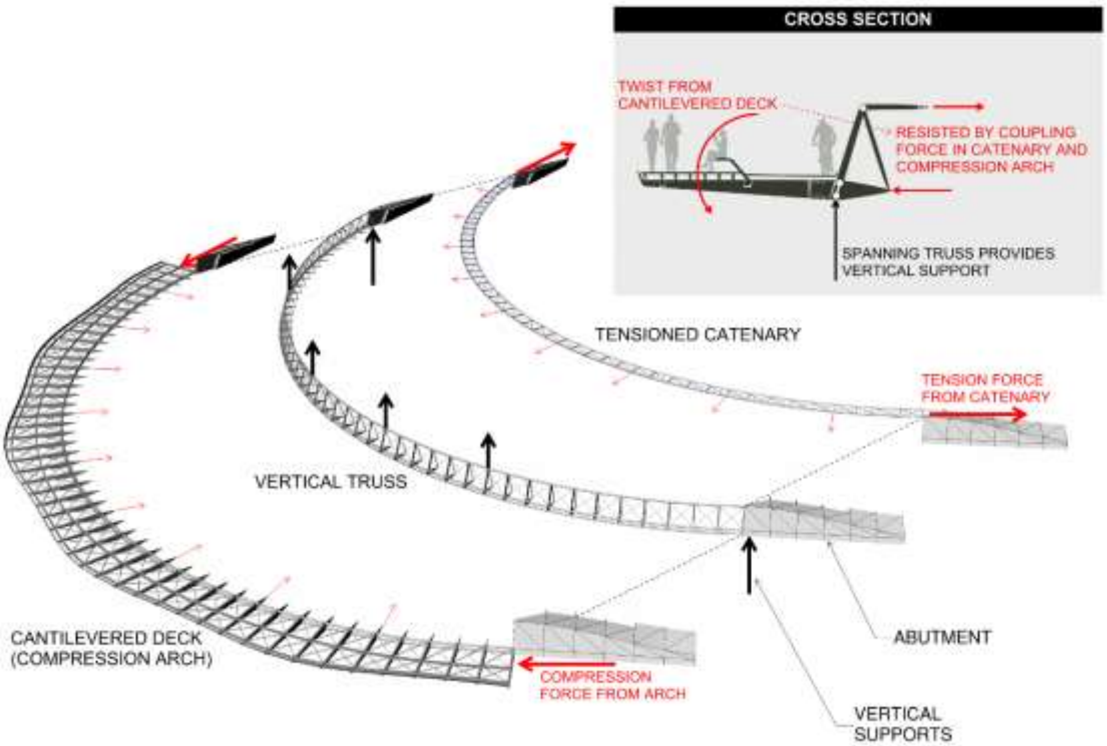
- The bridge threads its way under the road bridge, high enough to be above a 1 in 10 year flood event, while providing adequate headroom for cyclists as they pass under the road bridge
- High-performance and high-strength materials were incorporated into the bridge concept to adhere to its running theme of “nothing more, nothing less”
- It had to tie into the existing promenade levels at each end
- The new structure had to have minimal impact on upstream water levels in extreme flood events
- The bridge had to be perfectly circular in plan for the horizontal catenary to be stable
- The slope of the access points had to be reasonable out of respect for people with impaired mobility
- The truss nodes had to align favourably with the structure of the road bridge above to accommodate the connections to the support points

A 3D parametric model was created, which enabled all of the constraints to be tested at the click of a button and different geometries of the structure could be evaluated and easily modified. This meant that the geometry of the structure was resolved in a very short time. A job that would normally have taken weeks to resolve by traditional methods, the parametric model was used to determine the final geometry in hours.

Little room to manoeuvre | Photo by John Gollings

The structural concept
The curved nature of the path resulting from the above constraints required a unique structural solution. The cantilevered deck, in conjunction with the curved truss, is trying to twist the bridge structure downwards under its self-weight and applied loads.

The twist is resisted by a coupling force at the top and bottom of the truss as shown in the diagram below. The coupling force is uniform along the full length of the structure. As a result, the coupling force at the top can be resisted by a circular tensioned catenary. Only a circular shaped catenary is suitable to resist this load pattern. Similarly, the coupling force at the base is resisted by a compression arch.



The structural concept | Image by Aurecon

The result is a structural system that provides an open, sweeping path for cyclists and pedestrians while having very little interference in the river.

The tension catenary and the compression arch apply large tension and compression forces into the abutments at each end. The abutments are constructed from high strength concrete and are designed to resist vertical bending from the truss, as well as the horizontal torsion applied from the push-pull of the tension catenary and compression arch.

Advance dynamic analysis

As with any lightweight pedestrian bridge, careful consideration was given to the dynamic response that people would feel as they traversed the length of the bridge.

The design team took the client on the journey for them to understand the dynamic behaviour of pedestrian bridges. It was explained how bridges behave and how people respond to vibrations on bridges. Citing previous examples of where things went wrong, the relevance to this structure was explained and guidance sought from them as to what level of dynamic performance would be acceptable.

The client was open to allowing some movement in the bridge, to enhance the feeling of floating or hovering over the water. They wanted people to know when they had left terra firma and were on a spanning structure. They were very aware of the political sensitivity of bridge dynamics if the bridge did not perform as expected.

The structural engineers undertook extensive research into international best practice and local requirements. Ultimately, the Setra technical guide for footbridges was referenced, with limits not exceeding Australian Standards.

Keeping in tune with the client

The design criteria were then agreed with the client. The first modes of frequency of the structure were within the walking and jogging frequency range, so specialist computer software was used to undertake a detailed time-history acceleration response analysis. From this, it was determined that the bridge would require tuned mass dampers to limit the accelerations and prevent resonance.

The computer model subsequently included modelling of the tuned mass dampers, which gave the project team confidence that the dampers would achieve satisfactory results. In all, seven tuned mass dampers were installed at strategic points along the length of the structure.

After the bridge was constructed and the tuned mass dampers installed, on-site testing was undertaken with over 20 volunteers who marched in time to a metronome, set to the natural frequency of the bridge structure. Accelerometers were placed on the bridge structure to record the extent of movement. Analysis of the results showed that the accelerations were within the design criteria set at the start of the project.

Experiencing an exhilarating journey | Photo by John Gollings

MATERIALS

Sustainability, durability and simplicity
The choice of materials was founded on the philosophy that the best form of sustainability is achieved by minimising the volume of materials, in order to reduce the embodied energy that goes into a structure. For the Jim Stynes Bridge, high-performance and high-strength materials were selected, creating a structure that does more with less.

The main steel catenary and arch elements are made from high-strength steel (450 MPa) to minimise their size and mass. In a similar vein, the concrete abutments are formed with high strength, 80 MPa concrete to resist the large anchor forces. To minimise the overall weight of the precast concrete decking, high-strength concrete (65 MPa) was used, allowing the thickness to be as low as 75 mm.

All these elements combine to achieve a spanning structure that weighs just 3.5 kPa (achieving a maximum span of 40 m), supporting an ultimate live load of 8 kPa.

The result is a raw structure. All of its elements have a purpose, nothing more – nothing less. The materials that form the structure are also the finishes. It is robust and durable. In addition, the design of the bridge included reuse of existing infrastructure where possible, resulting in significant material and cost savings:

- Abandoned bridge piers were used to provide support to the new structure
- The existing piers of the road bridge were utilised to support the new structure
- Lateral stability was gained by connecting the new structure to the structurally stable, but abandoned, sheet piling

Other sustainability and cost-saving initiatives demonstrating reuse and multi-use elements that are implemented into the project are:

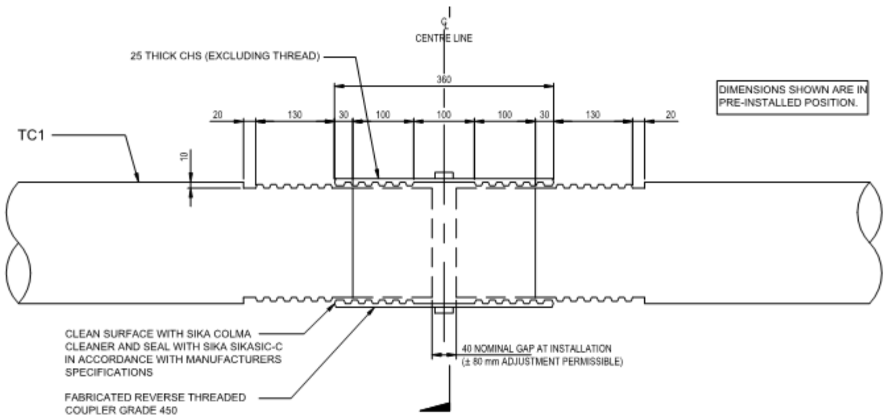
- One light fitting does both the statutory lighting and the specialist lighting. This is incorporated within the steel structure, providing a robust housing to the lighting with no additional cost
- Steelwork that was used to support the bridge in the temporary state was reused in the landscaping design as a feature element
- The retaining wall provides restraint against the lateral loads induced by the catenary structure

Combining clever design with high strength materials, and capitalising on existing structures on site, the new structure was cost-effective to build and requires little maintenance over its life.

Sustainable lighting solution showcased at night over the Yarra River | Photo by Cox Architecture

FABRICATION

In order to construct the bridge effectively, the steelwork was fabricated in 14 smaller modules. Each module was spliced together with tailor-made, stylised couplers that were nestled within the diameter of the steel members. Couplers were selected early in the design phase due to their ability to be rotated and thus expand or contract the splice connection to control deflections and provide on-site tolerance. This allowed for significant flexibility to adjust the position of the constructed bridge.



Typical coupler detail | Image by Aurecon

Split coupler | Photo by Aurecon

The modules were constructed within the fabricator's shop in sequential order and a trial of their connection to the next module was undertaken prior to delivery to site. This was critical in reducing the risk of misalignment on site and causing delays to the project. The modules were transported to site, loaded onto a barge and floated along the Yarra River to be lifted into position and suspended by temporary chain blocks to allow for future adjustments of the bridge deck.

Each module was connected to each other with the couplers. During the trial test runs in the steel fabricator shop, it was determined that turning each of the couplers simultaneously would be a difficult task to carry out while suspended over the river. To overcome this, the design team worked with the contractor to develop an innovative, slender split coupler that was capable of resisting the large tension loads. This allowed for each module to be manoeuvred into place with only one coupler requiring adjustment. Once in position, the split couplers were installed and any further minor adjustments were made.

COLLABORATION, CONSTRUCTION AND MAINTENANCE

Collaboration
The success of this ambitious project can be attributed to the entire team, who worked tirelessly to turn the idea into reality. It was one project where everyone involved in the project expressed their pleasure in working amongst such a cooperative and supportive group of people. The client believed in the design and allowed the design team to push the boundaries of structural design.

Everyone involved was part of the story. Where appropriate, the client supported the design team to keep the momentum going while stakeholder engagement and design reviews were being undertaken. The design team overcome the many challenges by maintaining an open and respectful relationship. No challenge was too big to overcome. The team came together, explored alternative solutions, and ultimately devised a solution that maintained the design integrity. During construction, the builder worked in close partnership with the design team. They took ownership of the design ambitions and strived to uphold its integrity with careful planning and attention to detail.

Instilled in the design is the theme of "nothing more, nothing less". The structure is pushing the limits of structural capacity in every aspect, resulting in a lean structure that is what it needs to be… nothing more. The design team wove together each discipline into a single, integrated design that was free of peripherals, but making use of what was essential.

The structure, for example, has been designed to house the specialist lighting which also double as the statutory lighting for security, facial recognition and safety.

This philosophy is carried through in many aspects of the design. It is an approach that gives good value for money by assigning multiple uses to single elements. The design used available elements, with no waste.

It was the faith of the client, the tenacity and talent of the design team, and the collaboration of the builder that got this structure built.

3D render | Image courtesy of Cox Architecture

Construction
With close collaboration amongst the design team, a construction methodology was developed to give certainty to the client that the bridge could be constructed. The contractor adopted the same principle that proved to be highly successful.

In essence, the modular bridge structure was supported along its full length by temporary works. Only after the complete bridge was constructed it was stable and able to support its own weight. The beauty of this scheme was the structure's ability to self-tension.

Simple statics and resolution of the load path dictated that when the bridge was released from its temporary supports after construction, the catenary and arch forces generated were not affected by locked-in stresses.

This led the design team to design the bridge in the pre-deflected position, which included up to 150 mm of vertical precamber. To communicate this to the fabricator, the design deliverable included a three-dimensional precambered computer model. The pre-cambered model was based on a detailed structural analysis of dead load deflections, so that they could be reversed in the fabrication prior to installation.

Once the bridge was released, a survey was undertaken to verify the position of the bridge. Following the survey, an analysis was then carried out to determine the adjustments required to each of the couplers in order to make minor adjustment to the position of the bridge to ensure it was positioned within acceptable tolerances. This process was extremely quick and easy to implement due to the procedures and design solutions regarding constructability that had been applied throughout the design stages of the project.

Maintenance
The materials that form the structure are also the finishes. These elements are inherently robust and, as a result, the entire bridge is durable and long lasting. This reduces whole-of-life costs by reducing maintenance and is inherently resistant against the usual instigators of maintenance – weather and vandalism. High quality and durable paint, high strength concrete slabs and Class 1 timber form all the finishes, making the bridge tough and durable for years to come.

Installing the modules | Photo by Traces Films

COSTS

The budget for construction was AUD12 million. The project achieved budget through value management and an open and honest working relationship with the client team, the builder and the design team.