Helix Pedestrian Bridge

The Helix Bridge is a landmark pedestrian bridge in Singapore, comprising a walkway surrounded by opposing double helix structures made from stainless steel. The design was inspired by the geometric helicoidal arrangement of DNA, which is seen as a symbol of continuity and renewal. The 280 m long bridge is the first double-helix bridge in the world and forms part of a 3.5 km continuous waterfront promenade, linking the Marina Centre, the waterfront area and a large casino/hotel resort. It is a very lightweight structure built almost entirely using duplex stainless steel.

Material Selection

Figure 1: General view of the Helix Bridge

Singapore has a dense urban environment with local planners placing a noticeable emphasis on quality urban design. Designers are encouraged to use sustainable, low maintenance and aesthetically pleasing materials. This can be challenging as the environment is hot, humid, industrial and coastal which can place significant demands on materials for both structural and architectural applications. Stainless steels give designers a good option to meet these demands as they are corrosion resistant materials and, provided the choice of grade is appropriate for the application, are a durable low maintenance solution.

The vast majority of the material used for the bridge, including the helices and support structures, was duplex stainless steel grade 1.4462 (S31803). This grade provides improved mechanical properties compared to austenitic steels.

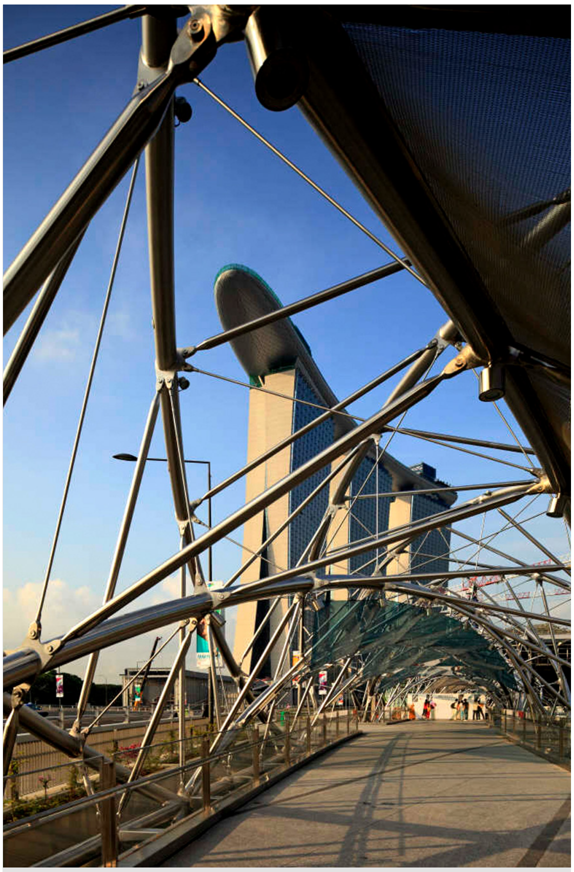

Figure 2: Pedestrian view through the bridge of the duplex stainless steel members

Duplex steels have a 0.2 % proof stress of 450 N/mm^2 compared to 220 N/mm^2 for austenitic steels. Where the strength of duplex steels can be utilised in the design it results in more efficient, lightweight and economic structures and can lead to weight savings compared with carbon steels. Duplex steels, in common with the austenitic stainless steels, are available with a range of durable architectural finishes.

For environments such as those prevailing in Singapore, it was essential that the chosen stainless steel had excellent long-term corrosion resistance. Several alloys could achieve this requirement but grade 1.4462 provides more than adequate resistance while meeting other requirements of good availability, cost effectiveness, ease of fabrication and the structural/architectural requirements. It also provides good fatigue strength as well as high resistance to stress corrosion cracking.

For the Helix Bridge, the cost of the duplex stainless steel was equivalent to the potential costs of using carbon steel. The amount of stainless steel required was significantly below that which would have been needed for a carbon steel bridge. Moreover, over the 100-year design life of the structure, cost analysis showed that stainless steel should provide a lower cost option than using carbon steel. The analysis took the initial construction costs including materials, fabrication and installation and the maintenance costs over the structure's life in to account. This is significant for carbon steels as repainting is required but is much less for stainless steels as the finishes do not require extensive maintenance.

The duplex tubes and plates were delivered in the mill-finish surface condition. Various finishes were specified throughout the structure; one of the helices was bead blasted whereas the other was highly polished.

Design

From the outset, the project posed several challenges. There was a desire for the plan view of the bridge to be curved in an arc, such that it joins the foreshore promenades on either side seamlessly. Furthermore, it was desirable to create a lightweight structure, in contrast to the adjacent 6-lane vehicle bridge which is rather heavy in appearance. Due to the tropical climate, the brief also required the bridge to provide shade and shelter against direct sunshine and heavy rainfall. The combination of these factors, together with the desire to create a landmark structure, led to a novel and unique design.

The bridge was designed using BS 5950 [1] in combination with a design guide from the SCI [2]. The resulting bridge comprises two delicate helix structures that act together as a tubular truss to resist the design loads. This approach was inspired by the form of the curved DNA structure. The helix tubes only touch each other in one position, under the bridge deck. The two spiralling members are held apart by a series of light struts and rods, as well as stiffening rings, to form a rigid structure. This arrangement is strong and ideal for the curved form. The stainless steel bridge is met by concrete abutments at either side.

Figure 3: Pedestrian view through the bridge, including shelter panels
(Photo: Arup)

Figure 4: Complexity of the opposing helices
(Photo: Arup)

Figure 5: Connection included welded and pinned joints
(Photo: Arup)

The 280 m bridge is made up of three 65 m spans and two 45 m end spans. If the steel were stretched out straight from end to end, it would measure 2.25 km in length. The major and minor helices, which spiral in opposite directions, have an overall diameter of 10.8 m and 9.4 m respectively, about 3-storeys high. The outer helix is formed from six tubes (273 mm in diameter) which are set equidistant from one another. The inner helix consists of five tubes, also 273 mm in diameter. Over the river, the bridge is supported by unusually light tapered stainless steel columns, which are filled with concrete. The columns form inverted tripod shapes which support the bridge above each of the pilecaps. The bridge weighs around 1700 tonnes in total.

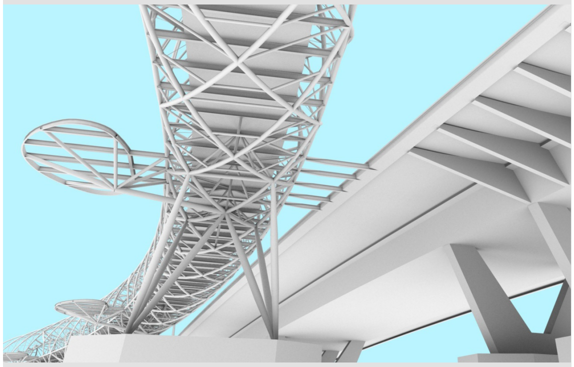

Figure 6: Schematic of the bridge details
(Photo: Arup)

The final pieces of the design are a series of ovular-shaped cantilevered viewing 'pods', each with capacity for about 100 people, that extend out on the bay side to create 'ring-side' viewing for water events. These decks are also constructed using grade 1.4462 and are designed to further optimize the pedestrian experience of the bridge as a new urban place and a vital connection between Singapore's major existing and emerging urban precincts.

Lighting

As this structure was inspired by the DNA structure, it was essential that the architectural lighting features should emphasise the various shapes and curves. Towards that end, a series of dynamic multi-coloured light-emitting diode (LED) lights are installed on the helix structures. Outward-facing lights accentuate the sweeping structural curves, with another discreet array of lights illuminating the internal canopy of glass and steel mesh to create a dynamic membrane of light. The inner helix uses white light to illuminate a path for pedestrians. The lights work particularly well with the surface finish and colour of the stainless steel elements.

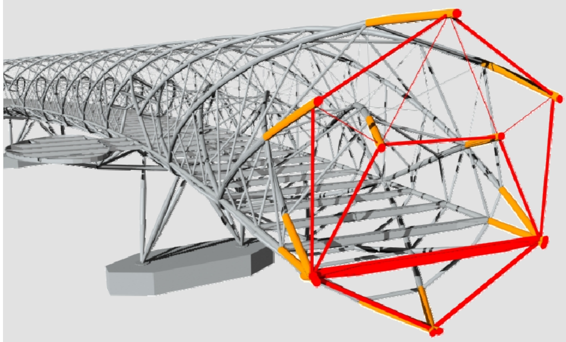

Figure 7: Three-dimensional model used to analyse forces
(Photo: Arup)

Analysis

Extensive numerical analysis was completed in order to explore possible solutions, using the engineer's in-house structural optimisation software. This enabled a method to be found of linking the two helices. It also ensured that the steel sections are used to their maximum capacity in supporting the pedestrian deck, shade canopies and light fixtures. Prior to specifying materials, or even finalising the designs, the bridge was fully modelled using three-dimensional software in order to visualise its form and geometrical compatibility, as well as to visualise the pedestrian experience on the bridge. Non-linear analysis was also carried out to assess the response under various load cases and to analyse the serviceability requirements such as vibration.

It was also important to carry out robustness studies in order to examine the behaviour that would arise if the structure were subjected to accidental or deliberate removal of a helix or supporting member [3].

Fabrication and Erection

The steel was delivered from the supplier in Europe to Singapore and then fabricated at a workshop in Johor, Malaysia. Major components of the bridge such as hoop members, deck beams, columns and viewing pods were fabricated from plate and pipe material. The bridge components were fabricated to the maximum transportable dimension, taking account of Singapore's road restrictions. The components had an average length of 11 m. In order to minimise delays and to identify any issues as early as possible, trial assembly of segments of the bridge was conducted in the workshop prior to transportation to site.

The delivery of material from Europe involved highly customised tubes and plates to meet the project's exacting product and logistic requirements. The main challenge during erection was to maintain a 50 m wide navigational channel with a safe overhead clearance for marine vessels. A temporary structural steel bridge was installed across the channel to enable erection of the permanent structure. Installation of the helix bridge began with the lower deck components and completed at the highest level of the bridge. This includes erection of the major and minor helices which were welded on-site and all the light struts and tension rods that hold and join the helices together using pins. Connecting the different components presented the biggest erection challenges and necessitated constant monitoring and checking.

Figure 8: Finished bridge in service
(Photo: Mah Guan Pang)

Information for this case study was kindly provided by Arup.

References and Bibliography

[1] BS 5950-1:2000 Structural use of steelwork in building. Code of practice for design. Rolled and welded sections.

[2] Structural Design of Stainless Steel, SCI, 2001.

[3] Carfrae T. and See L-M. The Helix Footbridge. Proceedings of the Conference on Structural Marvels, Singapore 2010.

Online Information Centre for Stainless Steel in Construction:
www.stainlessconstruction.com

Procurement Details

Client: Urban Redevelopment Authority, Singapore

Designer: Cox Group and Architects 61

Civil & Structural Engineer: Arup

Main contractor: Sato Kogyo Pte Ltd and TTJ Design and Engineering Pte Ltd

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