



Walking through the Marina Bayfront Pedestrian Bridge in Singapore will give you a feeling of passing through a huge DNA. Find out how Arup's engineers created the double-helix design using Bentley's 3D modelling software

**A**lthough Singapore's Marina Bayfront Pedestrian Bridge will be part of a walking route that passes a number of attractions, the bridge itself will be a destination. The bridge's striking stainless-steel exoskeleton was inspired by the double-helix shape of DNA, the genetic blueprint of life. The 6-metre-wide walkway is encircled by opposing double-helix structures, connected by struts that provide structural support.

The bridge spans 65 metre between piers for a total length of 280 metre. The bridge will link Singapore's central business district with the largest casino complex in the world, which is currently under construction on a reclaimed site on the southern bank of Marina Bay. The balconies spaced along the bridge will provide platforms for viewing the central business district and the bay. Computer-controlled lighting along each of the helices will transform the structure into an active element during evening fireworks and light shows.

The multicoloured lights will mimic the chemical processes involved in DNA replication.

Around 65 engineers, technicians and specialists from 14 different Arup offices contributed to the bridge project. The design team faced unique challenges as it began its work. The structural support mechanisms of the DNA-inspired structure of the bridge are different from all the other existing bridges. By balancing the unravelling forces of the opposing helices, the bridge can be constructed from significantly less steel—almost less than a fifth of the amount of steel required for a conventional box girder structure. The set out centre line adapts to the site's geometry. An aerial view shows that the bridge curves while simultaneously rising to a high point in the centre to allow passing ships. The helix geometry is necessarily complex as it incorporates the plane curve and vertical geometry within the constraints of the helix pattern. "Understanding this geometry and creating suitable drawings for

design and construction would simply not have been possible without a 3D model," said Greg Killen, Senior Associate, Arup's Brisbane office and the Design Manager for the project. In addition, a factor in the project's successful delivery was the ability to coordinate the complex geometry between the engineering analysis and documentation software. The workflow used during this project was based on the software's ability to transmit information among the applications used in the design process.

### Getting centred

Finalising the overall bridge centre line geometry entailed balancing three design goals. First, the bridge needed sufficient clearance for the shipping lanes below as well as a slope that was gentle so that people could move comfortably along the bridge. Second, the design also had to accommodate a link to a nearby vehicular bridge and allow the passage of pedestrians under the bridge at each abutment. Third, the bridge supports were to be located near the supports of the existing bridge to reduce the impact on ships using the bay.

By using Bentley's Generative Components, the design team was able to model the helix exoskeleton while still finalising the centre line geometry as they were confident that changes could be accommodated later. The design time

### Project Overview

**Project:** Marina Bayfront Pedestrian Bridge, Singapore

**Organisation:** Arup

**BE Awards Category:** Civil Structural Analysis, Design and Documentation

**Objective:** Design landmark pedestrian bridge with unique double-helix design

was compressed as different team members worked simultaneously on linked tasks.

Once the centre line was finalised using InRoads, it was imported into Generative Components and associated with the preliminary model of the double-helix geometry, which was created using an estimated centre line. The complete wire-frame geometry was regenerated in minutes. "Without GenerativeComponents, this regeneration would have required a custom script or elaborate parametric software," explained Ken Enright, 3D modeller at Arup. The firm then imported the wire-frame geometry into Bentley Structural. There it served as the foundation for a 3D model to generate construction drawings. A post-processed version of wire-frame geometry was imported into an analysis programme for structural analysis and design. This process was facilitated by DXF export capability of MicroStation.

The design team knew that it could reduce fabrication costs by approximating the double-curved helix geometry with a series of single-curved (planar) segments. The 3D model allowed the team to demonstrate that, using this technique, pedestrians would get the impression that they are walking through two smooth, double-curved spirals. Their experience would be similar to walking along a giant DNA molecule. TriForma and GenerativeComponents identified sets of repetitive components within the spiralling geometry, starting with the helix tubes. The required geometry resulted in slightly different tube bend radii for the hundreds of components that would make up the double helix. Hence, Arup took advantage of MicroStation Visual Basic macro capabilities to generate Excel spreadsheets and analyse the component geometry statistically. It then developed a new curve geometry that used only one bend radius for each of the two spirals that






formed the double helix. The new option was not extremely different from the true double helix, but it cut fabrication costs considerably. The speed of bending was increased, and the end waste normally associated with the cold bending process was reduced. This produced significant savings given the cost of stainless steel.

The Arup design team combined the results of the structural analysis with the Bentley Structural model using the Place Member Along Path tool, which allowed the 3D solid model to be quickly regenerated. The team used the Drawing Extraction technology of Bentley Structural to create as many drawings as needed to describe the complex design. Then, Arup used the software's reporting capabilities to generate a spreadsheet that contained accurate information and unique identifiers for every member within the structure. This information was provided at a tender as both a data file of coordinates and lengths and as tables on the tender drawings. This greatly assisted contractors in the tendering process. Once the structural design was in hand, the team turned its attention to the glazing panels that form a canopy for the bridge. The GenerativeComponents model was modified to include the generation of the complex panel arrangement. At first, the team feared that even after the helix rationalisation, all the glazing panels would end up in different sizes because of the bridge's geometry and the complex panel arrangement. Arup once again used Visual Basic to produce a

spreadsheet of all panel geometries. The design team analysed the geometries and proved that for a given tolerance, as defined by Arup's façade engineering team, the number of unique sizes could be reduced to 20, which could then be mass-produced.

The final proof of this plan was re-importing the analysis results back into the 3D model via Visual Basic for Applications (VBA). Each panel size was assigned a unique colour, which made the pattern of panel sizes immediately discernible. "Designing a fundamentally new kind of structure using material rarely used for pedestrian bridges was like sailing in uncharted waters," said Mr Killen. He further added, "Bentley's suite of products allowed Arup to develop flexible ways of working that enabled us to move without precedent with the necessary speed when faced with the inevitable challenges expected in a project."

Arup began its structural design work for the Singapore Urban Redevelopment Agency in June 2005. The estimated cost of bridge is approximately SGD \$68 million. Arup credits 3D modelling for translating the complex organic curves of the double helix into a functional pedestrian bridge. With the 3D model, Arup could standardise portions of the structure to facilitate construction and avoid premium costs that accompany projects with complex, non-repetitive geometry. 

Courtesy: Bentley Systems