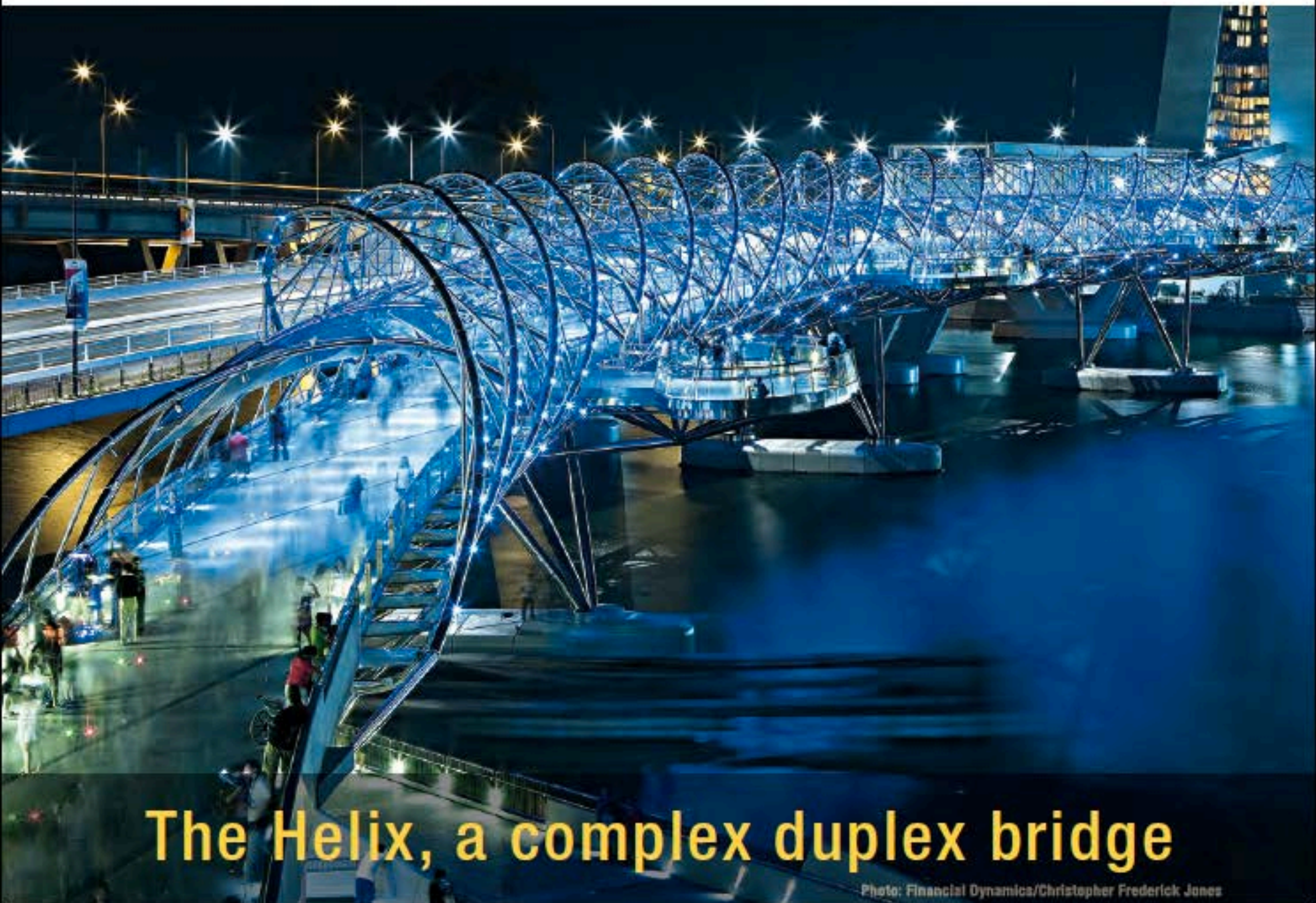


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The Helix, a complex duplex bridge

Photo: Financial Dynamics/Christopher Frederick Jones

The Helix, the new pedestrian bridge of Singapore's Marina Bay, was named for its resemblance to a DNA strand. It is an elegant, lightweight work of art. It is also a solid and corrosion-resistant structure, which brilliantly combines the use of advanced design tools and molybdenum-containing duplex stainless steel. Inaugurated in the summer of 2010, the Helix underscores the energy and vitality of this city-state.

With 5 million inhabitants concentrated over a surface area of barely 650 square kilometers, Singapore combines highly organized urban density with innovative and groundbreaking architecture. In addition to its strategic geographic location in the heart of the Malacca strait, it also serves an important role in Asia's economic and financial world. Singapore, known as the Switzerland of Asia, has become a top destination for tourists from all over the world.

In 2006, Singapore justified this flattering reputation by initiating a vast development program around Marina Bay, a lagoon located at the edge of the city-state's historic center, a highly popular area in recent years. The funnel at the bay's northern entrance, already crossed by an expressway, features a park with a floating stadium that hosted the Youth Olympics in August 2010. A few hundred meters away stands a replica of the London Eye ferris wheel, offering a breathtaking view of the marina!

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To the south is an imposing cultural and hotel complex of undeniable beauty and structural innovation. Projecting out into the bay, the Art & Science Museum rests on the water like an open lotus. Just behind it stands the audacious tripod of the Marina Bay Sands Hotel: three towers connected at their 200-meter summit by a 1.3-hectare park that is longer than the height of the Eiffel Tower and includes a 146-meter long infinity pool!



Overlooking Marina Bay, the lotus-shaped Art & Science Museum and the stunning three-legged Marina Sands Hotel. Photo: MBS-Newhome

The last link of a prestigious "Green Loop"

The entire edge of the bay has been developed as a 3.5-kilometer "green loop" trail enabling pedestrians to admire the architecture that illustrates Singapore's dynamism. To close the loop of this prestigious promenade, the Urban Redevelopment Authority (URA) of Singapore launched an international competition in 2006 for the design and construction of a pedestrian and vehicular link to connect both sides of the bay's entrance. A consortium composed of Australian and Singaporean architects and an international engineering firm developed the winning project. Their design showed great aesthetic and technical originality. A true architectural success, The Helix brilliantly concludes the development of Marina Bay.

The stroke of genius

The architects chose to reserve one bridge for vehicular traffic, thereby simplifying its design and allowing a greater budget for the pedestrian portion.

This enabled the pedestrian bridge to become the technical work of art we see today. Its structure and name, The Helix, are inspired by the spiral shape of a DNA strand, perfectly in line with Singapore's idea of its destiny: "life and continuity, rebirth and growth".

Because a single helix would not have been rigid enough, the designers' stroke of genius was to employ a double helix, with one nestled inside the other. The outer helix spirals clockwise, and the narrower inner helix spirals in the opposite direction. The two helices are connected by a hoop frame that reinforces them, making the structure perfectly stiff and creating an inner corridor for pedestrians. The designers had incredible vision to create such an elegant structure, but 3D software proved indispensable in bringing the intricate and complex design to life. In building the bridge, stainless steel was a logical choice from the outset. Aside from the purely mechanical aspects involved, the climatic conditions of Singapore heavily influenced the designers' choice of metals. The bridge would need to withstand the humid, tropical, and heavily salt-laden atmosphere of Singapore, as well as meet the design requirement of a 100-year minimum lifespan. Stainless steel enabled the designers to achieve these goals.

The Helix: choosing a high-performance steel

The choice of stainless steel was a key element of the project in light of the financial and mechanical constraints, as well as the manufacturing and maintenance specifications. The designers excluded painted steel as an option when it became apparent that the structure would be composed of a great number of individual components. The bridge's large metal surfaces and the many connecting and fastening points would all be exposed to the elements, and thus vulnerable to corrosion.

Although some stainless steel bridge projects use austenitic steels, engineers are increasingly using duplex stainless steels which offer a combination of very high corrosion resistance and mechanical properties. Engineers for The Helix continued this trend by specifying 2205 duplex stainless steel which they had used previously in the region on the Stonecutters Bridge in Hong Kong. Duplex 2205 is a two-phase alloy combining the qualities of ferritic and austenitic stainless steels.

The chemical composition of 2205 ensures a balanced microstructure that provides improved mechanical properties compared to single phase austenitic steels. The high chromium content and, most importantly, the molybdenum addition ensure high corrosion resistance, eliminating the risk of tea-staining and pitting that can occur on less highly alloyed stainless steels in humid, marine environments. →

Specifications and nominal composition of Duplex 2205

International steel N°		Chemical composition, % by weight, typical values					
EN	UNS	C	N	Cr	Ni	Mo	Others
1.4462	S32205, S31803	0.02	0.17	22	5.7	3.1	–

Chosen for its resistance to corrosion in a tropical environment, duplex stainless steel with molybdenum allows the design of a structure to be as aesthetic as it is robust.
Photo: Financial Dynamics/
Christopher Frederick Jones



The duplex alloy also reduces future maintenance costs which are limited to periodic cleaning of the structure. Thus, in building The Helix, 2205 duplex stainless steel was superior to austenitic and ferritic stainless steels. All these qualities are a direct result of the molybdenum present in the grade and played an essential role in the design team's material decision.

An economical design through duplex

Duplex 2205 provided a distinct design benefit due to its high strength. Superior mechanical strength, particularly in large spans where weight is critical, is necessary in structures like The Helix. The bridge weighs roughly 1,700 tons (equivalent to about 1,130 vehicles), but was designed to support itself, needing no supporting beams or cables. The 3D software allowed the designers to fully use the high strength of 2205 to optimize the structure's design and reduce the number of metal components.

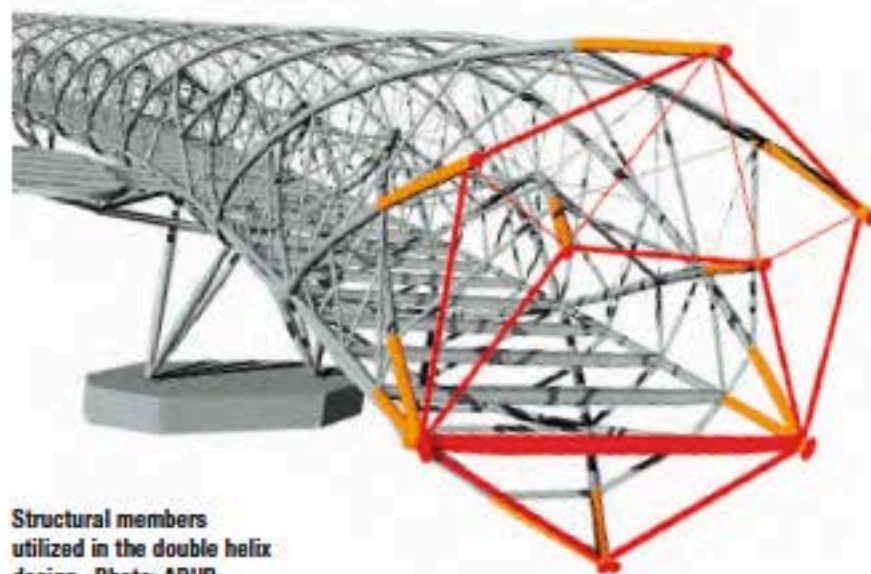
The structure consists of a 10.8-meter diameter outside helix and a 9.4-meter diameter inside helix. The outer helix is composed of a twisted strand of 6 tubes, while the inner uses only 5 tubes. The latter is offset vertically downwards in relation to the former, enabling them to cross at the pedestrian deck every 2.75 meters. Hoop frames composed of compression struts and tension rods interconnect them, ensuring the necessary stiffness. The stress calculations and the 3D design software ensured that the tubes of the two helices could have the same outer diameter of 273 millimeters (a major aesthetic criterion) without adversely affecting the functional specifications. The tubes' wall thickness varies only according to their location in the structure and the loads they support.

The 3D software allowed the designers to use only two bar sections for the two helices: a straight section and a slightly curved one, which minimized fabrication and erection costs. Moreover, the structure supports all ancillary equipment like the pedestrian deck, rain shields, and the impressive lighting system, without having to add further components. Simply put, the qualities of 2205 duplex

stainless steel and computer-aided design engineering simplified and streamlined the design. This smart design process enabled The Helix to use one-fifth the steel of a conventional box girder bridge of the same length, cutting down on material, construction, and maintenance costs.

Rigorous manufacturing and assembly requirements

The choice of 2205 also provided benefits in terms of component manufacturing and assembly. The Helix was manufactured in several segments due to restrictions on the type of trailer used and Singapore's traffic laws. A special off-site workshop was built to machine and assemble the segments. As many welds as possible were performed in this workshop to avoid contaminating the duplex with carbon steel likely to rust and stain the structure. Welding temperatures were strictly controlled to avoid modifying the phase balance of the duplex stainless steel, and to control its tendency to warp when heated, which could have affected the profile of the curved tubes. The tubes forming the two helices were butt welded while the struts and tension rods were securely bolted in place. These fabrication and assembly precautions guaranteed the integrity of the joints and assemblies. →



Structural members utilized in the double helix design. Photo: ARUP



Beneath the stainless steel curves, pedestrians are protected from the sun and tropical rain by shade canopies. Photo: Financial Dynamics/Christopher Frederick Jones

A masterpiece of elegance and lightness

The Helix's elegance comes from the outline of its curve and the originality of its reverse helices. The structure begins with a slow grade, where 12-meter long concrete ramps join the metal structure to each bank, and then curves slightly on the horizontal plane so the walkway runs alongside the vehicular bridge. The 280-meter spiral bridge consists of three central 66-meter spans and two 41-meter approach spans. The connections between spans rest on four concrete piles, each supporting a pair of inverted 2205 duplex stainless steel tripods. The 6-meter wide deck rests on 9-meter beams that connect each side of the double helix. Four elliptical viewing pods, positioned inside the curve of the bridge facing the spectacular view of Marina Bay, are cantilevered over the length of the span. The grace of The Helix is felt immediately due to the balance between the winding of the helices. The outer helix makes four complete turns while the inner helix makes five.

At the foot of the Marina Sands Hotel, The Helix offers the variety of its luminous ambiances. Photo: Kak Wai Lin

The new bridge can withstand the weight of 16,000 people. The behavior of the structure was tested to resist vibration phenomena caused by a large number of people moving at the same time, such as during marathons or parades. The walkway rises to 8.80 meters above the water between the piles, high enough to allow maritime traffic to pass between Marina Bay and the channel connecting it to the sea.

Adding to Singapore's skyline

Pedestrians are protected from the sun and tropical rains by a fine metal mesh and tinted glass canopy suspended between the upper hoops of the smaller helix. These also contribute to the bridge's gorgeous night-time appearance, enhanced by the lighting system whose integration and effects were taken into consideration during the design stage.

The finish of the stainless steel surface is particularly well suited to enhance the effects of the lighting arranged along the metal volutes of the inner helix and embedded in openings in the structural tubes. The metal components were beadblasted and polished with olivine (a magnesium silicate) to optimize the reflection of new-technology light emitting diode (LED) lights. They were also passivated to remove any trace of oxidation (discoloration) formed during welding and machining, and to form a protective passive film over their surfaces. Spotlights incorporated in the hoops of the outer helix illuminate the metal mesh sun screen and glass panels, causing them to glow at night. Finally, a series of lamps turned outward from the structure emphasizes the finesse and lightness of the curved helix. The lighting is programmed to vary in intensity and color to match the bridge's luminous ambience according to the occasion. The Helix not only serves as a remarkable engineering achievement and a unique pedestrian experience, it also adds to the majesty and natural beauty of Marina Bay and downtown Singapore. (tp)

