AKASHI KAIKYO BRIDGE

The Akashi Kaikyo Bridge (Japanese: 明石海峡大橋, Hepburn: Akashi Kaikyō Ōhashi) is a suspension bridge which links the city of Kobe on the Japanese island of Honshu to Iwaya on Awaji Island. It is part of the Kobe-Awaji-Naruto Expressway, and crosses the busy and turbulent Akashi Strait (Akashi Kaikyō in Japanese). It was completed in 1998,[1] and has the longest central span of any suspension bridge in the world,[3] at 1,991 metres (6,532 ft). Under the direction of John Bradfield of the New South Wales Department of Public Works, the bridge was designed and built by British firm Dorman Long of Middlesbrough (who based the design on their 1928 Tyne Bridge in Newcastle upon Tyne) and opened in 1932. The bridge's general design, which Bradfield tasked the NSW Department of Public Works with producing, was a rough copy of the Hell Gate Bridge in New York City. This general design document, however, did not form any part of the request for tender, which remained sufficiently broad as to allow cantilever (Bradfield's original preference) and even suspension bridge proposals. The design chosen from the tender responses was original work created by Dorman Long, who leveraged some of the design from their own Tyne Bridge which, though superficially similar, does not share the graceful flares at the ends of each arch which make the harbour bridge so distinctive. It is the eighth longest spanning-arch bridge in the world and the tallest steel arch bridge, measuring 134 m (440 ft) from top to water level. It was also the world's widest long-span bridge, at 48.8 m (160 ft) wide, until construction of the new Port Mann Bridge in Vancouver was completed in 2012.

HISTORY

The Akashi Kaikyo Bridge forms part of the Kobe-Awaji-Naruto Expressway, the easternmost route of the bridge system linking the islands of Honshu and Shikoku. The bridge crosses the Akashi Strait (width 4km) between Kobe on Honshu and Iwaya on Awaji Island; the other major part of the crossing is completed by the Ōnaruto Bridge, which links Awaji Island to Ōge Island across the Naruto Strait.

Before the Akashi Kaikyo Bridge was built, ferries carried passengers across the Akashi Strait. A major passageway for shipping, it is also known for its gale, heavy rain, storms, and natural disasters. The Sekirei Maru sinking in 1945, which killed 304 people, first stirred public discussion on the possibility of a bridge over the span. In 1955, two ferries sank in the Shiun Maru disaster during a storm, killing 168 people. The ensuing shock and public outrage convinced the Japanese government to develop plans for a bridge to cross the strait.

Investigations for a bridge across the strait were first conducted by the Kobe municipal government in 1957, followed by an evaluation by the national Ministry of Construction in 1959. In 1961, the Ministry of Construction and Japan National Railways jointly commissioned the Japan Society of Civil Engineers (JSCE) to conduct a technical study, and the JSCE established a committee to investigate five potential routes between Honshu and Shikoku. In 1967, the committee compiled the results of the technical study, concluding that a bridge across the Akashi Strait would face "extremely severe design and construction conditions, which have no similar examples in the world's long-span bridges" and recommending additional study.

CONSTRUCTION

The original plan called for a mixed railway-road bridge, but when construction on the bridge began in April 1988, the construction was restricted to road only, with six lanes.

Actual construction did not begin until May 1988 and involved more than 100 contractors. The Great Hanshin Earthquake in January 1995 did not do substantial damage to the bridge due to anti-seismic building methods. Construction was finished on time in September 1996. The bridge was opened for traffic on April 5, 1998, in a ceremony officiated by the Crown Prince Naruhito and his spouse Crown Princess Masako of Japan along with Construction Minister Tsutomu Kawara.

The towers are located in an area of strong tidal currents where water velocity exceeds 7 knots (about 3.6 m/s). The selected scour protection measure includes the installation of a filtering layer with a thickness of 2 m in a range of 10 m around the caisson, covered with rip raps of 8 m thick.

The bridge has four substructures: two main piers (located beneath the water) and two anchorages (on land). These are denoted 1A, 2P, 3P, and 4A in sequence from the Kobe side. 1A consists of an underground circular retaining wall filled with roller-compacted concrete, 2P and 3P are circular underwater spread-foundation caisson structures, and 4A is a rectangular direct foundation. 2P is located at the edge of the sea plateau at a level depth of 40–50m and a bearing depth of 60m, and 3P is located at the symmetrical point to 2P with respect to the bridge's center, at a level depth of 36–39m and a bearing depth of 57m.

The bridge has three spans. The central span is 1,991 m (6,532 ft), and the two other sections are each 960 m (3,150 ft). The bridge is 3,911 m (12,831 ft) long overall. The two towers were originally 1,990 m (6,530 ft) apart, but the Great Hanshin earthquake on January 17, 1995 (magnitude 7.3, with epicenter 20km west of Kobe) moved the towers (the only structures that had been erected at the time) such that the central span had to be increased by 1 m (3.3 ft). The central span was required to be greater than 1500m to accommodate maritime traffic; it was concluded before construction began that a larger span between 1950 and 2050 meters would minimize construction costs. The bridge was designed with a dual-hinged stiffening girder system, allowing the structure to withstand winds of 286 kilometres per hour (178 mph), earthquakes measuring up to magnitude 8.5, and harsh sea currents. The bridge also contains tuned mass dampers that are designed to operate at the resonance frequency of the bridge to dampen forces. The two main supporting towers rise 282.8 m (928 ft) above sea level, and the bridge can expand because of heat by up to 2 m (6.6 ft) over the course of a day. Each anchorage required 350,000 tonnes (340,000 long tons; 390,000 short tons) of concrete. The steel cables have 300,000 kilometres (190,000 mi) of wire: each cable is 112 centimetres (44 in) in diameter and contains 36,830 strands of wire.

DESIGN

Strauss was the chief engineer in charge of the overall design and construction of the bridge project. However, because he had little understanding or experience with cablesuspension designs, responsibility for much of the engineering and architecture fell on other experts. Strauss's initial design proposal (two double cantilever spans linked by a central suspension segment) was unacceptable from a visual standpoint. The final graceful suspension design was conceived and championed by Leon Moisseiff, the engineer of the Manhattan Bridge in New York City.

Irving Morrow, a relatively unknown residential architect, designed the overall shape of the bridge towers, the lighting scheme, and Art Deco elements, such as the tower decorations, streetlights, railing, and walkways. The famous International Orange color was Morrow's personal selection, winning out over other possibilities, including the US Navy's suggestion that it be painted with black and yellow stripes to ensure visibility by passing ships.

Senior engineer Charles Alton Ellis, collaborating remotely with Moisseiff, was the principal engineer of the project. Moisseiff produced the basic structural design, introducing his "deflection theory" by which a thin, flexible roadway would flex in the wind, greatly reducing stress by transmitting forces via suspension cables to the bridge towers. Although the Golden Gate Bridge design has proved sound, a later Moisseiff design, the original Tacoma Narrows Bridge, collapsed in a strong windstorm soon after it was completed, because of an unexpected aeroelastic flutter. Ellis was also tasked with designing a "bridge within a bridge" in the southern abutment, to avoid the need to demolish Fort Point, a pre–Civil War masonry fortification viewed, even then, as worthy of historic preservation. He penned a graceful steel arch spanning the fort and carrying the roadway to the bridge's southern anchorage.

Ellis was a Greek scholar and mathematician who at one time was a University of Illinois professor of engineering despite having no engineering degree. He eventually earned a degree in civil engineering from the University of Illinois prior to designing the Golden Gate Bridge and spent the last twelve years of his career as a professor at Purdue University. He became an expert in structural design, writing the standard textbook of the time. Ellis did much of the technical and theoretical work that built the bridge, but he received none of the credit in his lifetime. In November 1931, Strauss fired Ellis and replaced him with a former subordinate, Clifford Paine, ostensibly for wasting too much money sending telegrams back and forth to Moisseiff. Ellis, obsessed with the project and unable to find work elsewhere during the Depression, continued working 70 hours per week on an unpaid basis, eventually turning in ten volumes of hand calculations. With an eye toward self-promotion and posterity, Strauss downplayed the contributions of his collaborators who, despite receiving little recognition or compensation,[23] are largely responsible for the final form of the bridge. He succeeded in having himself credited as the person most responsible for the design and vision of the bridge. Only much later were the contributions of the others on the design team properly appreciated. In May 2007, the Golden Gate Bridge District issued a formal report on 70 years of stewardship of the famous bridge and decided to give Ellis major credit for the design of the bridge.