SYDNEY HARBOUR BRIDGE

The Sydney Harbour Bridge is a heritage-listed steel through arch bridge in Sydney, spanning Sydney Harbour from the central business district (CBD) to the North Shore. The view of the bridge, the harbour, and the nearby Sydney Opera House is widely regarded as an iconic image of Sydney, and of Australia itself. Nicknamed "The Coathanger" because of its arch-based design, the bridge carries rail, vehicular, bicycle and pedestrian traffic. 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 longspan bridge, at 48.8 m (160 ft) wide, until construction of the new Port Mann Bridge in Vancouver was completed in 2012.

HISTORY

There had been plans to build a bridge as early as 1815, when convict and noted architect Francis Greenway reputedly proposed to Governor Lachlan Macquarie that a bridge be built from the northern to the southern shore of the harbour. In 1825, Greenway wrote a letter to the then "The Australian" newspaper stating that such a bridge would "give an idea of strength and magnificence that would reflect credit and glory on the colony and the Mother Country".

Nothing came of Greenway's suggestions, but the idea remained alive, and many further suggestions were made during the nineteenth century. In 1840, naval architect Robert Brindley proposed that a floating bridge be built. Engineer Peter Henderson produced one of the earliest known drawings of a bridge across the harbour around 1857. A suggestion for a truss bridge was made in 1879, and in 1880 a high-level bridge estimated at £850,000 was proposed. In 1900, the Lyne government committed to building a new Central railway station and organised a worldwide competition for the design and construction of a harbour bridge. Local engineer Norman Selfe submitted a design for a suspension bridge and won the second prize of £500. In 1902, when the outcome of the first competition became mired in controversy, Selfe won a second competition outright, with a design for a steel cantilever bridge. The selection board were unanimous, commenting that, "The structural lines are correct and in true proportion, and... the outline is graceful". However due to an economic downturn and a change of government at the 1904 NSW State election construction never began.

CONSTRUCTION

Bradfield visited the site sporadically throughout the eight years it took Dorman Long to complete the bridge. Despite having originally championed a cantilever construction and the fact that his own arched general design was used in neither the tender process

nor as input to the detailed design specification (and was anyway a rough copy of the Devil's Gate bridge produced by the NSW Works Department), Bradfield subsequently attempted to claim personal credit for Dorman Long's design. This led to a bitter argument, with Dorman Long maintaining that instructing other people to produce a copy of an existing design in a document not subsequently used to specify the final construction did not constitute personal design input on Bradfield's part. This friction ultimately led to a large contemporary brass plaque being bolted very tightly to the side of one of the granite columns of the bridge to makes things clear.

The official ceremony to mark the "turning of the first sod" occurred on 28 July 1923, on the spot at Milsons Point on the north shore where two workshops to assist in building the bridge were to be constructed.

An estimated 469 buildings on the north shore, both private homes and commercial operations, were demolished to allow construction to proceed, with little or no compensation being paid. Work on the bridge itself commenced with the construction of approaches and approach spans, and by September 1926 concrete piers to support the approach spans were in place on each side of the harbour.

As construction of the approaches took place, work was also started on preparing the foundations required to support the enormous weight of the arch and loadings. Concrete and granite faced abutment towers were constructed, with the angled foundations built into their sides. Once work had progressed sufficiently on the support structures, a giant "creeper crane" was erected on each side of the harbour. These cranes were fitted with a cradle, and then used to hoist men and materials into position to allow for erection of the steelwork. To stabilise works while building the arches, tunnels were excavated on each shore with steel cables passed through them and then fixed to the upper sections of each half-arch to stop them collapsing as they extended outwards.

Arch construction itself began on 26 October 1928. The southern end of the bridge was worked on ahead of the northern end, to detect any errors and to help with alignment. The cranes would "creep" along the arches as they were constructed, eventually meeting up in the middle. In less than two years, on Tuesday, 19 August 1930, the two halves of the arch touched for the first time. Workers riveted both top and bottom sections of the arch together, and the arch became self-supporting, allowing the support cables to be removed. On 20 August 1930 the joining of the arches was celebrated by flying the flags of Australia and the United Kingdom from the jibs of the creeper cranes.

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.