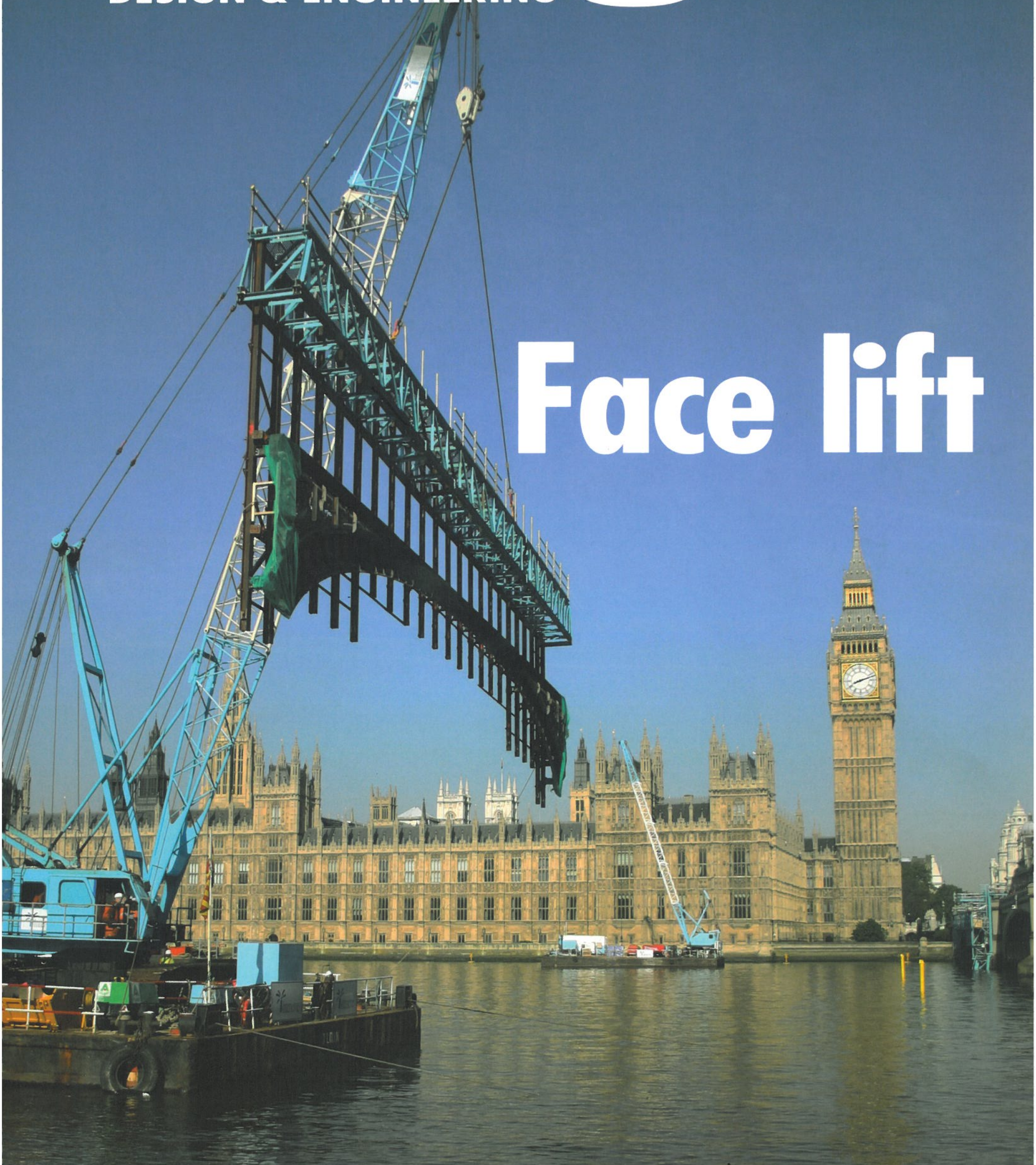
Bridge
DESIGN & ENGINEERING



Face lift

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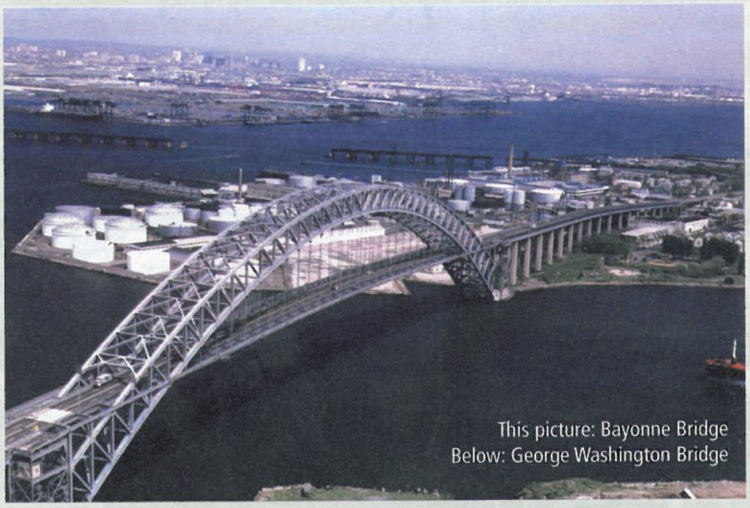
Ammann's masterpieces reach 75

Two iconic bridges owned by the Port Authority of New York & New Jersey have celebrated their 75th anniversaries within the space of three weeks. The George Washington and Bayonne bridges are very different structures – one a suspension bridge and the other an arch - but they have much in common. Both were designed for the Port Authority by Othmar Ammann and opened under budget, months ahead of schedule. Both were record breakers, and both have been given 'most beautiful' accolades.

As the Port Authority's chief engineer, Swiss-born Ammann planned and supervised construction of both bridges as well as the Lincoln Tunnel. His career also included responsibility for many other major projects, including the design and supervision of the Verrazano-Narrows bridge.

The two-level George Washington Bridge spans the Hudson River from Manhattan to New Jersey and forms part of the US Interstate I-95 highway. It cost US$59 million to build – considerably less than the original estimate – and opened eight months early. From its opening, it was recognised as an engineering marvel. It was the world's longest suspension bridge when it opened to traffic on 25 October 1931 with a span of 1,067m - nearly twice as long as any bridge built before it – suspended from steel towers soaring 184m above water level. French architect Le Corbusier described the resulting structure as 'the most beautiful bridge in the world'.

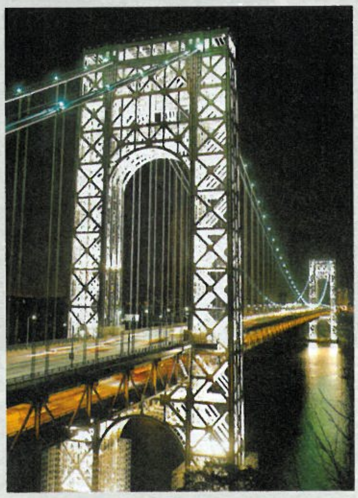


This picture: Bayonne Bridge
Below: George Washington Bridge

The bridge's length between anchorages is just over 1,450m. Four suspension cables are anchored into an 84,000m^3 concrete block on the New York side, while 153,000m^3 of solid rock had to be excavated for the New Jersey anchorage.

It remains vital to the region's economy and now carries 107 million vehicles a year, which is said to make it the world's busiest bridge. Its ability to cope with modern traffic levels stems from the innovative foresight of the Ammann's design.

There were relatively few vehicles on the road when the bridge was planned in the 1920s but the design anticipated a surge in car ownership. The central strip was left unpaved, which enabled two more lanes to be added as traffic grew in the 1940s. Opening of a lower deck in 1962 provided six additional lanes and brought it to today's 14-lane total.



The steelwork has been regularly repainted for continued protection and has undergone a US$54 million rehabilitation in recent years including a complete repainting of the towers.

Its engineering importance was recognised from the outset and it has received engineering, architectural and design awards throughout its life, including designation in 1981 as a National Historic Civil Engineering Landmark by the American Society of Civil Engineers. The nearby Bayonne Bridge received the same accolade four years later.

The bridge is recognised around the world as a symbol of New York City, particularly on national holidays when it flies the world's largest free-flying flag, which is 18m by 27m.

Bayonne Bridge remains one of the world's longest steel arch bridges and its arch span of more than 510m makes it one of the most spectacular bridges in the New York metropolitan area. It links Staten Island with New Jersey and is an important part of the region's highways as well as providing a channel clearance of more than 45m at mid-span to enable the passage of ocean-going vessels.

Ammann's design featured a slender, slightly taperd hyperbolic curve over the roadway and the arch trusses are made up of a pattern of repetitive regular triangles. It was the first major bridge to use manganese steel for its main arch ribs and rivets. Another innovation was in its use of record-breaking falsework which avoided the need for heavy anchorages at the shores. The bridge opened to traffic on 15 November 1931 and was awarded a "most beautiful steel bridge" prize by the American Society of Civil Engineers the same year.

None of its primary structural elements needed replaced until 1999, when the Port Authority began a US$33 million deck rehabilitation.

Lisa Russell

FINAL LIFT

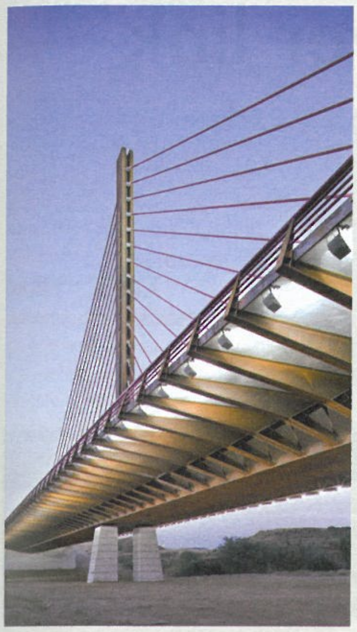
The last segment of the Lai Chi Kok viaduct in Hong Kong was erected in August, the final of 1,766 segments which have been installed by the VSL Hong Kong/Acciona alliance. The project is part of Route 8 and will connect Tsing Yi Island to Shatin.

The scope of works for the alliance includes installation of post-tensioning, bearings and movement joints as well as the erection of the segments. The majority of this section consists of two parallel box girders, in addition to which

there are two slip roads at the south end and two at the north. The deck is supported on piers, most of which are 25m high, but some of which are up to 45m. The pier and superstructure layout varies from single pier to portal for one to four box girders, depending on the location. The project is in the middle of a highly-populated part of Kowloon, which meant that the contractors faced restrictions and obstacles at all times. The 172m-long launching gantry, weighing around 1,000t, was designed to be able to move sideways by 45m, enabling it to erect all four parallel box girders simultaneously. At one pier, where a bridge movement joint was located, six half cantilevers covered seven traffic lanes at ground level and four lanes on two elevated flyovers.

The Shenzhen Western Corridor lifting frame was used for segment erection on double, parallel box girders. It is equipped with a strand-lifting system which allows it to lift segments from the ground on either side of the parallel bridge decks. This was useful for locations where one of the box girders was over an inaccessible area such as the open channel at Lai Chi Kok.

The West Tsing Yi lifting frame, after some modification, was used for piers with single box girders where access



SINGULAR SOLUTION

A new cable-stayed bridge was opened in July in the city of Guadalajara, close to Madrid in Spain. The bridge is 201m long and carries the road over the Henares River; it is 30m wide and is believed to be the widest of its kind in Spain. The bridge, designed by Estudio AIA and built by Ferrovial, has a central plane of stay cables and a single tower located between the two carriageways. There are 28 cables anchored at 6m intervals along the deck. The strands are seven-wire 15.7mm diameter, grade 1860 and cables vary in size from 33 to 41 strands.

The deck of the bridge is formed of a composite section consisting of a continuous concrete slab 250mm thick at the top in the main span, over a box steel section, and a double composite section with a concrete slab in the top and in the bottom in the secondary span. The 30m width includes two carriageways of 12.5m each, with a 3m gap between the decks, where the central tower is located. The steel section of the deck is made of grade S-355, and the concrete slab of C45/50.

Depth of the steel box is 2.5m, and it is 11m wide at the top, and 9m wide at the bottom. It is open at the top, and the steel structure is connected to the concrete slab via connector-type studs.

In terms of the box steel section, the web thickness varies from 15mm to 25mm, the bottom flange thickness varies from 15mm to 20mm, and the top flanges are made of plates with dimensions varying from 500mm by 25mm to 500mm by 40mm.

The top slab is extended outside the steel box to achieve the total width; this slab is supported by cantilevers with a transverse length of 9.3m which are connected to the steel box at 3m centres along the bridge.

The single tower is at the centre of the bridge, and is made of steel S-355. It rises 60m above the deck and is fixed at its connection with the deck. The double-T section is 3m by 2.55m and it has anchors for stay cables every 2.5m.

The substructure consists of intermediate supports, abutments and foundations. The intermediate supports and abutments are made of white concrete C30/35, and the foundations are made of grey concrete C25/30. At the intermediate supports of the bridge, foundations consist of 1500mm-diameter piles extending up to 25m in length. The bridge was built on temporary concrete pier supports until the stay cables were installed and tensioned. The client for the project is the Junta de Comunidades de Castilla-La Mancha.

close to the pier was possible but where the rest of the ground below the box girder cantilever was inaccessible; for example on steep slopes. This was equipped with two strand-lifting units, and was used with the long upper cross-beam and segment-lifting beam to allow the erection of segments at the pier shaft, followed by launching of the lifting frame and segment to the tip of the cantilever.

To get the precast segments into a confined location, a sliding and support system was designed and installed. The segments were then lifted by crane on to one end of the sliding system and moved up to 80m to the other end of it. The whole operation was complicated by the fact that the bridge was curved, had a longitudinal gradient of up to 4% and piers in the way.

A tie-down system was also designed to counteract the permanent works movement and to retain the box girder in the correct location during construction. Up to 350t of load was applied at a distance of up to 8.5m from the centre of the pier; temporary support towers were also required.