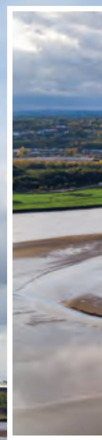


The Outright Winner

2018 CONCRETE SOCIETY AWARDS

Mersey Gateway Bridge

Widnes–Runcorn, Cheshire

The Mersey Gateway Bridge is unique in being the UK's only long-span cable-supported bridge constructed primarily using in-situ concrete, thus representing a significant advancement in the material's application for this purpose. Innovative construction methods, such as the mobile scaffold system, enabled the bridge to be constructed on time and within budget.

Above: The completed bridge, which opened in October 2017.

The project was conceived in the 1990s when it was identified that the capacity of the Silver Jubilee Bridge (SJB) could no longer sustain the traffic demands of the region. A result of this increasing lack of resilience in the transport network meant that both local and regional development were being impaired and opportunities for growth constrained.

After several years of planning, the project received initial approval from the Department for Transport in 2006, with full funding secured in 2011.

Tendering began in March 2012, procured by Halton Borough Council under a design, build, finance and operate process with a 30-year concession period. The Merseylink Consortium was identified as preferred bidder in May 2013, reaching financial close in March 2014. Achieving completion of the project within a challenging three-and-a-half-year construction programme, the bridge was opened to the public in October 2017.

In addition to the main crossing, the scheme also provided:

- 2.3km of new and 4.5km of upgraded highways
- seven new junctions
- 12 new smaller bridges, modification and remedial works to existing structures and remediation of contaminated land.

The project will lead to the creation of thousands of employment opportunities in the local area, instigate a 20-year programme of regeneration activity in Halton Borough and promote inward investment in the region. The remodelling of the SJB will prioritise the use of public transport and encourage a shift towards walking and cycling, leading to significant social and environmental benefits.

Design and construction

For a project of this scale, the key to success depended on the integration of construction practices into the design process, including the impact that major temporary works have on the design. This was exemplified in the construction of the approach viaducts, which adopted a mobile scaffold system (MSS).

Principal criteria behind the selection of concrete over other conventional construction materials such as steel were the cost-effectiveness of achieving the desired design, cost certainty and long-term durability and maintenance. This was

Panoramic view of completed bridge. *(All photos: Merseylink Civil Contractors Joint Venture.)*

driven by the concession companies' desire to avoid maintenance repainting within the concession term and fully supported by the owner's concern in the longer term.

By standardising the design of the major structural components and by using high-strength concretes, the project team could achieve the highest quality, increased safety, streamlining of the construction programme and, most notably, build an elegant structure that belies its sheer mass and scale.

Cable-stayed bridge foundations

Each pylon foundation was required to support vertical loads of over 500MN and overturning moment due to the deck of 900MNm. The solution was for a spread footing of approximately 22m diameter and 4.5m thick, whose base was founded some 10m below river bed level at each of the pylon locations. This approach met the objectives of the project team, avoiding the need for deep foundations to be constructed in the middle of the river and minimising the potential impact on the environment.

They were constructed over a 30-hour period inside temporary double-skinned cofferdams with an inert sacrificial membrane. A radial reinforcement arrangement was used, together with up to 1400m^3 of concrete (strength-class C40/50 and CIIIB cement type).

Pylons

The slender cable-stayed bridge mono-pylons are the most visually prominent element of the bridge. The objective was to detail them such that they were as elegant as possible, while at the same time being fast to construct. Each is octagonal in cross-section, with wall thicknesses varying from 800 to 600mm. They taper gently from deck level in the longitudinal direction and, in the upper pylon sections, are a constant 3.5m wide.

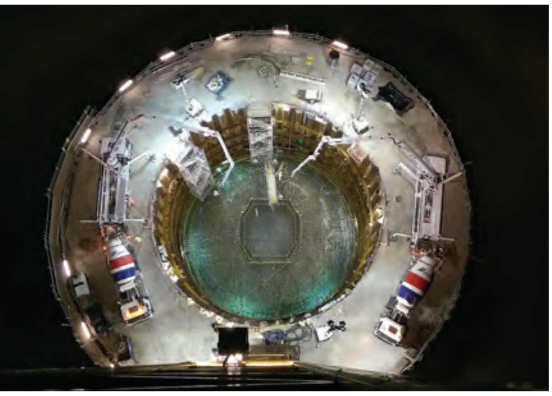
The north and south pylons comprise a lower pylon, hammerhead (which supports the bridge deck) and upper pylon. The central pylon differs as it has a fixed integral connection between it and the deck, in place of a hammerhead.

The sections were constructed in 5m lifts, each taking approximately five days to construct using C60/75 strength-class concrete and reinforcement bars up to 40mm diameter to resist the substantial compressive loads from the concrete deck. Reinforcement cages were preassembled to minimise working at height in an exposed environment and led to improved quality and reduced construction cycle times.

The pylon hammerheads were technically challenging, both in design and construction, owing to their geometric complexity and the high concentrated loads. These not only provide support to the main deck but also are located at the junction between the upper and lower pylons. Transverse post-tensioning across the upper surface of the hammerhead catered for the large tensile forces and vertical post-tensioning restrained the deck during the balanced cantilever construction phase. 3D modelling of the hammerhead geometry was required to allow production of accurate reinforced concrete (RC) drawings and to conduct necessary clash detection.

Cable-stayed bridge deck

The post-tensioned RC deck features a single plane of central cables and a continuous single-cell concrete box girder, 4.6m deep, 33m wide, with transverse post-tensioned ribs at 6m centres and a transversely post-



South cofferdam pylon base concrete pour. Some 1400m^3 was placed in over 25 hours.

MSS 'Webster' on the first span of the south approach viaduct – October 2016.

Central pylon pier table. Falsework dismantling ahead of upper pylon construction.

tensioned deck slab. Steel delta frames are provided at each stay location to distribute the horizontal component of the stay force into the concrete top flange and transfer the vertical component to the bottom of the webs via precast anchor blocks. Longitudinal external post-tensioning tendons are provided inside the deck box, which were stressed once balanced cantilever construction had been completed.

Each deck segment, weighing approximately 320 tonnes, was constructed in 6m lengths. C-shaped form travellers, each weighing 270 tonnes, provide improved access to the top of the segment during construction.

A cycle time of five to six days per segment was targeted, with concrete strength of 25MPa at 22 hours on a characteristic cube strength of 60MPa a key requirement. Preassembled reinforcement cages were adopted in the bottom slab, webs and top flange cantilevers. To facilitate early stressing of the deck transverse post-tensioning, precast edge blocks were provided.

Approach viaduct foundations

The approach viaduct foundations comprise 1.5m-diameter bored cast-in-situ piles that extend up to 50m below ground level to the underlying sandstone.

A key feature of the design and construction of the deep approach viaduct foundations at the northern end of the bridge was the need to cater for the risk of causing disturbance to existing contaminants and the possibility of introducing preferential contaminant pathways to the underlying aquifer. Through extensive dialogue with the Environment Agency, and after risk assessments, it was concluded that the risk of introducing these pathways could be reduced to acceptable levels by installing a protective secant pile cut-off wall around the pile cap prior to construction.

Approach viaduct piers

The approach viaduct piers each comprise a hollow RC pier stem and RC pier head. This was to minimise materials use and further environmental disruption within the estuarine salt marshes by keeping foundation footprints to a minimum. The single pier elements support the continuous approach viaduct deck at around 70m centres and are proportioned to ensure no uplift on the bridge bearings.

Approach viaduct deck

The approach viaduct deck is structurally continuous with the cable-stayed bridge deck, resulting in a total uninterrupted bridge length of 2.25km between expansion joints. The non-uniform plan geometry required consideration of the effects of lateral loading on bearings and piers arising from creep, shrinkage and thermal movements. This eliminated expansion joints that would normally be required within the length of the deck, so reducing long-term maintenance.

Two self-launching MSSs, each weighing approximately 1350 tonnes, were used to construct the north- and south-approach viaducts (706m and 544m respectively). Although MSSs have been used to cast similar spans before, 70m was at the upper end of the economic range. Use of the MSS

North pylon hammerhead – upper pylon first lift under construction; assembly of form traveller at cofferdam level.

allowed in-situ concrete construction cycle times that were three to four weeks per span.

The deck construction was divided into the three main stages. First, the central 'bath-tub' box, comprising the bottom flange, webs and transverse ribs, were cast using the MSS, which was supported by the pier at the leading end. This was cast in a single pour of around 1200m^3 over a 30-hour period. After the MSS had been launched to the subsequent span, the top slab between webs was cast. In the final stage, a separate wing form traveller cast the cantilevers.

Key benefits of this approach were that access for removing the inner formwork was simplified, the concrete volume (and therefore mass in Stage 1) was minimised and casting the top slab and cantilever wings was de-coupled from the technically complex MSS operation. Due to the geometric complexity of the deck cross-section, trials were carried out to refine the concrete mix design and demonstrate adequate consistence retention, flow and compaction around the section.

Internal longitudinal post-tensioning negated the complexity associated with restricting the internal void for formwork assembly and removal. Around 50% of the longitudinal cables are terminated at the transverse construction joint, with the remaining 50% coupled to cables that continue to the next span. This reduced congestion near the transverse construction joint.

Post-tensioning tendons were stressed throughout the staged construction process once the concrete had gained its 28-day characteristic strength typically three days after casting. Transverse post-tensioning tendons were stressed after Stage 3 was completed. ■

Mersey Gateway Bridge, Widnes–Runcorn, Cheshire

Client	Halton Borough Council (Mersey Gateway Crossings Board)
Client's representative	Mersey Gateway Crossings Board
Client's technical and contractual advisors	Ramboll/CH2M Hill/Knight Architects
Finance	Merseylink Consortium – Macquarie Capital (Australia), BBGI & FCC Construcción
Contractor	Merseylink Civil Contractors (MCCJV) – Samsung/FCC/Kier
Design team	Merseylink Design Joint Venture – COWI/AECOM/Fhecor/Eptisa
Architect	Merseylink Architectural Advisor – Dissing + Weitling
Ready-mixed concrete supply	CEMEX UK Materials

South pylon form traveller; south span form traveller launched from pier table.

Final concrete beams installed on the Astmoor Bridgewater Viaduct section.

The Judges' Comments

The range of concretes produced here had to perform to very tight tolerances and varying strengths. The challenge of consistently delivering and placing 117,000m^3 of concrete, over a 29-month, 24/7 construction period in the main bridge was successfully met using two batching plants, one at each side of the river, and by using hot and cold water and insulated formwork as required. GGBS has been used extensively; rapid strength was less of an issue and by using concrete, future maintenance has been minimised.

There is very good execution and consistent finish throughout, aided by the use of CEM I in many strength-critical locations.

The bridge is unique in the UK – it is the first of its type to be constructed using in-situ concrete facilitated by the innovative use of the MSS and other travelling forms. In spite of full in-situ working, the safety record was exemplary.

Flood-lit at night, the three-pylon bridge is iconic, elegant, slender and in full harmony with the Mersey estuary. Its contemporary design provides plenty of modern concrete on view for motorists crossing. This structure represents a significant advancement in concrete's application for bridge construction. It works as a big bridge should.