Tees Barrage Bridge, Cleveland

Completion: 1995
Client: Teeside Development Council
Architect: The Napper Partnership
Structural Engineer: Ove Arup & Partners
Main Consultant: Montgomery Watson (UK) Ltd
Main Contractor: Tarmac Construction

The Tees Barrage, designed to retain a constant water level and provide vehicular access from the A66 and A19, is a catalyst for the regeneration of Teesdale, 100ha of derelict land along the River Tees close to Stockton town centre.

The scheme used the permanent water level created by the barrage as a focus for waterside development along new canals, a stream, lake and the riverside. The project involved master-planning and detailed design of the barrage, a navigation lock, a fish path, canoe slalom course, warm-up lake and caravan and camping site.

Barrage Design Competition

Teesside Development Corporation organised a competition for the architecture of the barrage. The centrepiece of The Napper Partnership's winning entry was a tubular steel arch bridge crossing the barrage. The bridge had to carry the highest standard loading specified by the Department of Transport (45 units of HB loading) so that future industrial development would not be restricted by the capacity of the bridge. That highway load amounted to approximately 10 times the design load of the customary use, in roofing, of such unusual tubular structures.

The Barrage Bridge

The 1 60m long main (road) bridge has eight 17.5m spans. At each end of the four river spans, the road crosses the roof of the barrage pavilion and then an approach bridge with two identical 17.5m spans. The arches have a rise of 5m, which gives clearance to the navigation channel and service roads. The final design contains 360 tonnes of 406.9, 329.9, 298.5, 244.5 and 193.7CHS Grades 50D and 55EE together with 280 tonnes of plates and cast steel. More than half of the steel was curved before delivery into the workshop for fabrication. Exposed steelwork is protected by a sprayed metal coating and 250mm of acrylated rubber-based paint (DTp paint scheme type 1-AR). The inside surfaces of the tubular members are protected from water ingress by the sealed, fully welded construction.

Design Development

The first design task was to determine the structure's behaviour and the method of fabrication. Cold bending of tubes to the radius required for the infills was impractical, as was forming a structural connection between two tubes ideally touching at a single point with a common tangent. A cast steel solution was developed, with the nodes cast separately and joined with tube-to-tube butt welds (concept design). A simple computer model demonstrated, however, that both arch ribs and circular infill members needed to be larger than in the competition entry. Adding casting radii where the two tubular sections 'touched' gave a long length of connection, and the tubular appearance of the smaller tube was lost over this length (first solution)

A constructive dialogue between the engineer, who knew what was possible, and the architect, who knew what he wanted, led to the arches being separated at the joints and a flat 'plate' section being introduced between them to form a connection. The number of infills was reduced and a clear space left between them, to maintain the structure's transparency'(adopted solution).

Design Stresses

The form of the bridge means that the combination of pinned supports and a continuous deck is necessary. Thus, changes in the temperature of the bridge cause stress in the steelwork. To increase the member size would have been counter-productive because an increase in stiffness in one member would increase the stresses in all the other members. Grade 53 steel was therefore chosen for the rolled tubular members to increase capacity without a corresponding increase in stiffness.

Detailed Design

Much of the thrust in the arch at the supports is transmitted through the infill members into the deck at midspan. The proportion of vehicle load carried by a single arch depends on the position of the axles on the span. To quantify these effects, a 2000 element spaceframe model of the whole bridge was developed and analysed on a Sun Sparc workstation using Oasys GSA software. Thirty-one live load cases were analysed for a standard vehicle crossing the bridge and were combined with the effects of temperature change and support settlement. In all, 279 load cases were examined.

The pairs of main arches were separated to give spans for the concrete deck of 2.75m and 3.6m, which allowed transverse steelwork supporting the deck to be omitted. Horizontal bracing members rather than cross-bracing were used between the pairs of arches.

Bridge Parapets

A decorative parapet, complementing the circular motif of the arches, was provided, supported on shaped pre-cast cantilevers. Because this parapet could not meet the standards for containment of vehicles, a separate, standard P2 highway bridge parapet was provided beside the highway

Fabrication

The combination of tubular steel, solid castings and thick plates in such unusual shapes was a challenge for fabricator Westburv Tubular Structures. Half-arch end (24) and double half-arch internal (20) frames were produced over approximately six months. Full penetration butt welds on tubes up to 50mm thick were required, and welding dominated fabrication, taking 35,000 hours. Grade 50 and Grade 55FE rolled steel was used, and A4 (modified) cast steel, which gave properties equivalent to Grade 50. The induction bent tube needed further heat treatment after testing to ensure adequate toughness. MIG welding was used for all welds, with an electrode containing 2.5% nickel. Extensive preheat and controlled cooling were required throughout. Non-destructive testing on 100% of butt welds and on 40% of fillet welds was carried out 48 hours after welding. In addition, immediate post-weld NDT by the fabricator enabled early identification of defects. The weld procedures followed led to a very low defect rate.

Erection

The prefabricated arch frames were brought to site as special loads, on purpose-adapted trailers, and were erected by 70 tonne - 310 tonne mobile cranes standing on the bed of a diverted river, with proprietary trestling at midspan giving temporary support. After the line and level of the arches had been checked, the main butt welds in CHS up to 25mm thick were made. These had to be in a specific sequence and be subject to ambient temperature restriction, which meant some night welding. MMA techniques were used for all site welds and the fabricator had a welding technician on site throughout. Fillet welding of the cross bracing between arches generally followed the main butt-welding. The full paint system was applied to all site-welded areas. These entailed shot blasting, metal spraying and spray application of topcoats

Tower of Lights

The provision of a ‘tower of lights’ on the central pier of the barrage was required by the client in order to announce and celebrate the entrance to the Teesside site. This takes the form of a single 29m tall tubular steel mast in 610 CHS tapering to 355.6 CHS. The mast is stabilised by guys formed from Macalloy bars up to 34mm diameter. Mast and guys support reflective globes and plates, while the light source is located at the base of the tower for ease of access for maintenance.

Barrage Footbridges and Lifting Bridge

A simply-supported footbridge and cycleway is provided, at a height of +5.0m OD, with river spans of 14m between piers formed from twin universal beams and steel plate deck. This allows the public to come close to the barrage structure and river environment. The footbridge carries the hydraulic and electrical power to the south pavilion and to the internal barrage piers for the gate mechanism. The footbridge crosses the navigation channel in the form of a steel lifting bridge that can be raised by a simple hydraulic jack to an angle of 80 degrees.

The Bridge Environment

The entire Tees Barrage development is contained within a new woodland structure of some 120,000 native trees and shrubs which reinforce the landform and screen heavy industry to the north-east, drawing attention instead to Teesdale and, behind that, the North Yorkshire Moors. The planting complements Portrock Marshes to the east of the barrage, an area of local wildlife inportance