Erskine Bridge

over the River Clyde for the Scottish Development Department

Bridgework section SPECIAL AWARD

STRUCTURAL ENGINEERS
Freeman, Fox & Partners

STEELWORK CONTRACTORS
Fairfield-Mabey Ltd

United Kingdom entry for the Structural Steel Design Award competition being held by the European Convention for Structural Steelwork.

Judges' Comments

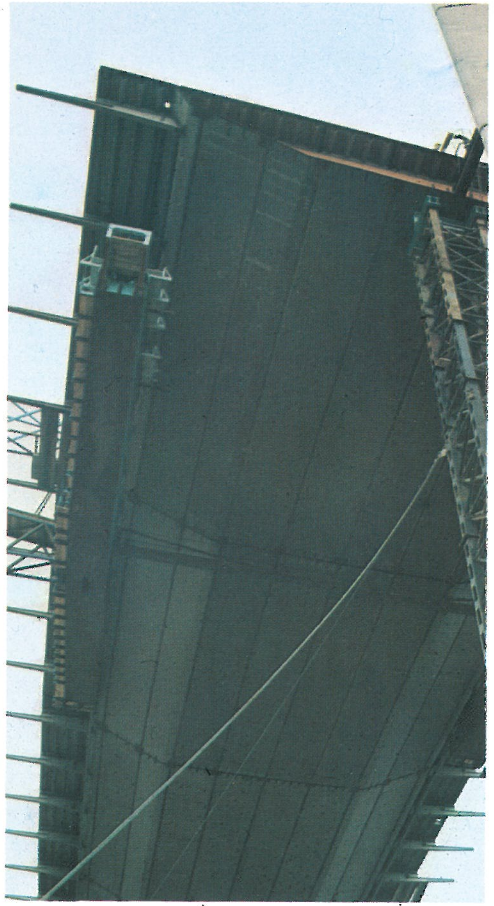
This graceful bridge must be one of the most elegant steel structures designed and constructed in the United Kingdom and has the longest span for its type in the world. The unsupported spans have probably the largest span-to-depth ratio known in bridge engineering. It is one of the finest examples of courageous British engineering resulting in a structure which meets the highest standards of elegance and economy.

The Erskine Bridge and its approach roads provide an important north/south connection over the Clyde estuary about 9 miles west of Glasgow, joining the A82 and the A8 trunk roads. It accommodates dual 24ft wide carriageways, two 8ft wide cycle tracks and two 8ft wide footways and carries four 24in dia. water mains, two 12in dia. gas mains, post office, electric and bridge service cables. The bridge superstructure is 4,334ft long comprising a main cable-stayed span of 1,000ft with two side anchor spans of 360ft each, and viaduct approaches consisting of seven 224ft spans and one 206ft on the north bank, and three 224ft spans and one 168ft on the south bank. Any river span much less than 1,000ft would have required a pier which would have necessitated expensive protection against possible impact from passing vessels. The 1,000ft cable-stayed span with piers out of reach of vessels, and built in the dry, was the optimum economic solution.

The approach viaducts are curved in plan at both ends to a 2,550ft radius, with 280ft long transition curves connecting to the straight section over the river and anchor spans. In elevation the central 2,246ft has a vertical curve of about 28,000ft radius and is flanked on either side by 1 in 25 gradients. These curves in plan and elevation, together with the necessary superelevation, were built into the box girder steelwork.

The welded box girder is basically 65ft wide and 10ft 6in deep with the top flange cantilevering beyond the box on either side. The shape resembles an aeroplane wing with an overall width of 97ft 6in on the approach viaducts and 102ft 6in on the main spans where the extra width is required to accommodate the steel towers and the cables in the central median. The all-welded hollow aerofoil shaped box is continued throughout the bridge.

The top flange (the deck plate) is $\frac{1}{2}$in thick high yield steel reinforced by V-shaped stringers ap-



proximately at 2ft centres which are supported by full depth diaphragms, generally at 14ft centres. The roadway and cycle tracks are surfaced with $1\frac{1}{2}$in mastic asphalt. The footways consist of steel panels surfaced with $\frac{1}{2}$in mastic asphalt.

The superstructure is supported on fourteen piers and two abutments. Fixed knuckle bearings are provided at all piers except the rather short pier no. 14 which has roller bearings. These are also provided at both abutments and the main expansion joint which is located at about $\frac{1}{4}$ point of span 7–8, i.e. 2,616ft from the south abutment. The south abutment is designed to act as a fixed anchorage for this length of the superstructure. The northern 1,718ft length of the superstructure is fixed to the six piers which are designed to resist all longitudinal forces, pro rata to their stiffness. Estimated movement at the main expansion joint is $\pm$21in and the north abutment$\pm$3in. The water and gas mains are supported under the footways on sliding PTFE bearings which permit expansion and contraction movements (about$\pm$21in) of the pipes relative to the bridge superstructure.

The main river span is additionally supported by the cable stays at approximately $\frac{1}{3}$ points. The single plane continuous cables pass over saddles on top of 125ft high towers set on the centre line of the bridge above the main river piers. Each cable is built up from twenty-four 3in dia. strands arranged in four layers of six. Each 3in strand is composed of 178 spirally laid galvanized wires 0.198in dia. The minimum specified breaking load of each strand is 500 tons, and the designed working dead load is 170 tons. They are anchored in special chambers built into the box girders in the main spans and the ends of anchor spans at piers 4 and 7.

The towers are rectangular all-welded steel boxes tapering from 5ft 6in × 4ft 6in at the base to 4ft to 3ft 6in at the top made up of $1\frac{1}{2}$in thick high yield steel. The plates are internally stiffened and filled with high strength concrete (7,500 psi) designed to act compositely with the steel. The tower sits on a rocker bearing at deck level to enable it to swing longitudinally under varying loads.

The heavy diaphragm over the main pier incorporates an extension of the tower inside the box-girder to transmit the tower load through the box to a main central knuckle bearing on the pier. Thus the main pier carries three knuckle bearings, the central one carrying tower loads, and two outer bearings carrying girder loads.

Outstanding features of the bridge are:

The proportions of the box girder. The overall depth of 10ft 6in for unsupported spans of up to 360ft results in one of the largest span to depth ratios in the world, while the aerofoil shape of the box, developed to reduce wind drag and provide maximum aerodynamic stability, emphasizes the slenderness of the structure.

Fabrication procedure. The steelwork was fabricated in the shops into the largest transportable panels and sub-assembled at site in special jigs into complete boxes weighing up to 170 tons. The welding of these large units closely resembles modern ship building practice.

Standardization. Maximum use was made of standardization of panel dimensions by providing for camber and curvature only by slight changes in end bevels of panel and half diaphragm plates.

Continuous spans. By provision of a rolling leaf expansion joint at about mid-length of the structure, continuous spans of 2,616ft and 1,718ft could be supported by knuckle bearings on piers which accommodate longitudinal temperature movement of the deck by flexure, thereby permitting slender piers – which contribute greatly to the aesthetics of the bridge to be used.

1,000ft main span. This is the largest single cable stayed span constructed to date in the world.

Deck troughs. For the first time in this country, the V-trough stiffeners for the battledeck were produced by cold rolling from strip at the fabricating shop.

Weight of steel. Some 11,700 tons of fabricated steelwork were used in the superstructure, giving a minimal weight of 61 lb/ft^2 for spans with an average length of 289ft.

Erection plant. A novel and very sophisticated erection method was developed which enabled box sections up to 160 tons in weight to be erected in full cantilever in the space of a few hours. The box sections were matched to each other after sub-assembly to ensure correct fit-up in the air and then lifted on to the already erected section of the bridge by means of a large purpose-designed gantry crane. Deck bogies were utilized to transport the box sections to the erection front where they were then transferred to the launching girder and lowered into position by operation of a control system incorporating hydraulic rams and screwed rods. Low friction sliding bearings and an hydraulically controlled levelling device enable correct attitude and positioning of the box section to be achieved prior to welding the transverse joint.

The final cost of the bridge and foundations (excluding services installation) was about £11.50 per sq. ft of deck demonstrating the economy which can be obtained with a steel bridge of this type.