The Design and Construction of M8 St James Interchange Improvement

James McCafferty and Michael Hackney
Scott Wilson Kirkpatrick & Partners (Scotland)

Introduction

By the late 1980's, it had become clear that traffic congestion caused by the restricted capacity of the overhead roundabout at St James Interchange on the M8 adjacent to Glasgow Airport was so serious that major improvements were required.

On behalf of the Scottish Office, Strathclyde Regional Council (SRC) studied the problem and recommended that direct links be constructed from the A740 (Linwood) to and from the M8 over the existing interchange.

In 1989 a decision was made to promote the project as a Fixed Price Design and Construct Competition.

The Design Construct Competition

The project was advertised in the EC Journal in September 1989. Of the thirteen firms which expressed interest, six provided the required further details and were interviewed in December 1989. From these Balfour Beatty/Scott Wilson Kirkpatrick was one of the three consortia invited to tender.

Documents were issued in May 1990 and Tenders were to be returned by January 1991. SRC provided the Specifications and all other documentation including the geometry, a 'MOSS' ground model and photographs for large photomontages.

Tenders were assessed by SRC and in April 1991, Balfour Beatty, having submitted the lowest Fixed Tender Sum and being lowest by the method of assessment, were awarded the Contract.

Final design commenced immediately followed by construction in September 1991, with completion due in August 1993.

Preliminary Design of Viaducts

There were two major structures to consider; Viaduct A which carries eastbound traffic from the A740 onto the M8 Motorway and Viaduct B carrying traffic in the opposite direction.

Both viaducts are curved in plan with superelevations up to 5%, gradients up to 4% and a maximum height above ground level of approximately 15 metres.

Ground conditions at the site consist of alluvium and glacial till overlying mudstone and sandstone up to 40 metres down.

Various forms of deck construction and span arrangements were considered and discussed with Balfour Beatty. It was clear that, due to the very poor ground conditions and the restrictive nature of the site, a prestressed post-tensioned concrete superstructure was not going to be competitive and so was rejected. Similarly, prestressed pre-tensioned beams were rejected due to their weight and the difficulty in achieving continuity of the superstructure.

Steelwork was the obvious material for the superstructure. Following discussions with the contractor, steel boxes were rejected due to their high fabrication cost and it was concluded that a superstructure comprising four steel plate girders acting compositely with a reinforced concrete deck slab would be the most suitable solution.

Having established the form of the deck construction, the next important decision was to finalise the span arrangements to arrive at the most economic overall scheme. This involved striking a delicate balance between the cost of the deck and the deep-piled foundations. There was also a requirement to provide an aesthetically pleasing solution which would satisfy both the promoters of the project and the Royal Fine Art Commission for Scotland.

An overall construction depth of 2.5 metres had been allowed by SRC in their design of the viaduct geometry. A simple estimating exercise was undertaken to compare superstructure and piled foundation costs for various continuous spans in the range 40 metres to 50 metres.

This indicated that the use of the spans of 50 metres would be the most cost-effective solution.

Furthermore the standard 50 metre span complemented the spans required to cross existing and future roads and the railway crossing. These crossings were dictated by site restrictions, clearances and the desire of the consortium to adopt right spans where possible for ease of design and construction. The only skew span is where Viaduct A crosses the existing M8 Motorway.

Finally, the positions of the abutments were fixed by comparing the cost of the viaduct with that of the piled approach embankments.

This process led to the choice of a 16 span structure for Viaduct A, with an overall length of 790 metres and a 15 span structure for Viaduct B, with an overall length of 740 metres.

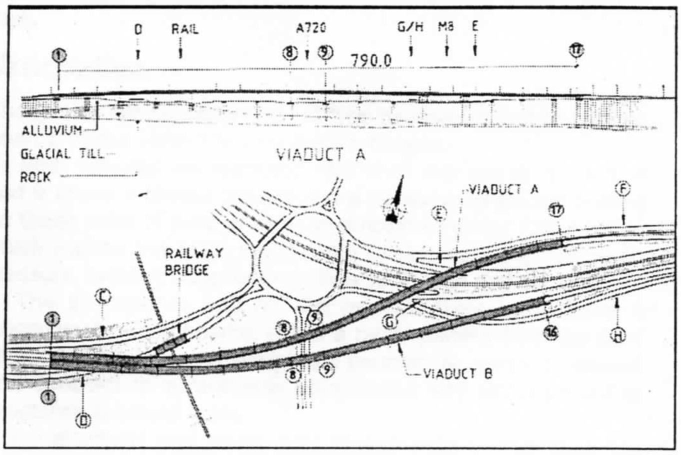
Spans are generally of the order of 50 metres with the largest span on Viaduct A being 64 metres skewed at 65° and on Viaduct B a 67 metre right span crossing route D.

Details of Viaduct Superstructures

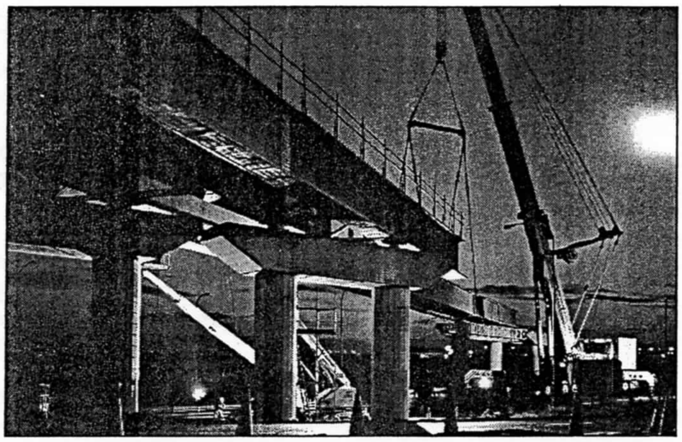
The viaducts have identical cross sections, the overall width of the deck being 12.4 metres. The width of the carriageway, kerb to kerb is 10.0 metres and verge width is a constant 0.6m on both sides.

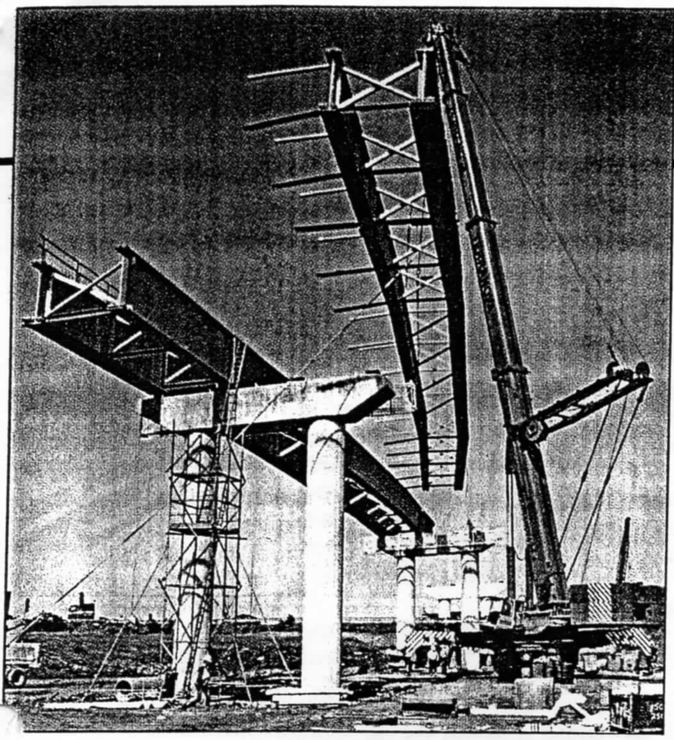
The four plate girders have a constant depth of approximately 2.1 metres and are straight between site splices. At piers, the transverse spacing of the girders is 3.1 metres. At midspan, the spacing is slightly less.

Layout of Viaducts.



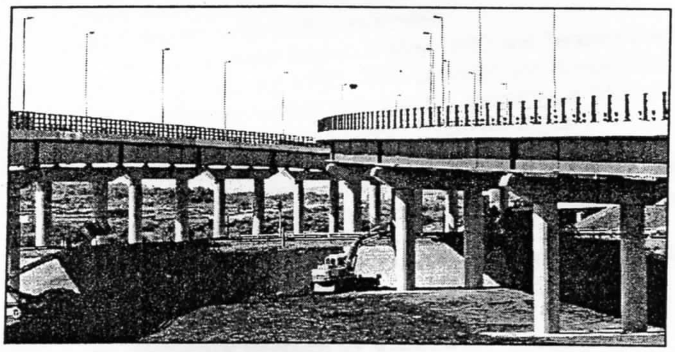
Girders being erected over M8 during night-time possession.





Erection of paired girders for Viaduct B.

View of completed Viaduct.



The deck slab follows the plan curvature of the road and acts compositely with the plate girders through traditional shear stud connection. The deck slab cantilevers, are approximately 1.5m long but vary in length to accommodate the curved deck slab and straight beams. The deck slab, 250mm thick over the inner girders increases to 320mm over the outer girders to resist transverse bending of the slab due to the very onerous collision loading on the P6 high containment steel parapets and to accommodate deck drainage gullies.

The Design Brief required grade 40/20A concrete for the deck slab and an increase in the minimum code requirements for cover to the top reinforcement to 50mm.

Top flanges are generally 500 to 550mm wide with thicknesses varying from 20m to 40mm.

On outer girders, the bottom flange is generally 900mm wide with a maximum width of 1440mm at the largest span. Thicknesses vary from 32mm at midspan to 75mm over piers.

On inner girders the bottom flange is generally 650mm wide but again, this increases to 850mm at the largest span and thicknesses vary from 25mm to 75mm. Where possible, flange sizes are designed to permit the use of standard steel flats.

Webs vary in thicknesses from 18mm at piers to 14mm at midspan, but increase to 25mm on the longer spans. In all cases, there was a need to strike a balance in economy between steelwork weight and the cost of welding stiffeners to the webs.

To ensure clean lines for the structure, it was decided that there would be no stiffeners on the outer faces of the outer girders except at bearing locations.

Provision has been made for jacking of the superstructure from the tops of the pier crossheads; this requires additional stiffeners on the girders over the jacking points fore and aft of the main bearings.

To prevent lateral torsional instability, pairs of girders are restrained by simple triangulated bracing comprising 150 x 150 equal angles. Braced pairs are then connected by link bracing to ensure that wind loads are shared by all four girders during construction.

The site connections are made using HSFG general grade bolts size M24 and the main girder splices are located to suit available plate/flat lengths and maximum transportable lengths.

All steelwork is grade 50D and is protected using a paint system appropriate for an 'Inland B' environment with 'Difficult' access.

The Royal Fine Art Commission for Scotland approved of graphite as the final top colour in agreement with our view that this would ensure a crisp, clean appearance for the structures.

Construction and Erection

Construction of both viaducts commenced at the anchor piers near the centre of the viaducts.

Erection of the steelwork was in braced pairs progressing in both directions from the anchor piers. G.R.P. non-participating formwork was then quickly laid between the girders to support the slab during concreting.

Once a sufficient length of steelwork had been erected, the main deck slab construction commenced to a predetermined sequence.

The construction sequence ensured that midspan sections were cast before adjacent pier sections to limit tensile strains in the deck slab in hogging regions over the piers. Furthermore the slab was constructed such that there were never more than two spans 'out-of-balance' about the fixed piers. This limited the out of balance frictional bearing restraint forces applied to the fixal points to manageable levels. Cantilevers and copes were constructed later using travelling shutters running along the deck slab.

Articulation

The girders are supported on pot type bearings bolted to tapered bearing plates welded to their bottom flanges.

Both viaducts are anchored near their mid points at Piers 8 and 9 where a pinned bearing and a transversely guided bearing on these pairs of piers provide an articulated portal frame action which resists the large longitudinal forces resulting from wind pressure, braking, out-of-balance bearing friction and the like.

The abutments and all the intermediate piers have a longitudinal guided bearing set in a radial pattern from the fixed point. This minimises restraint and permits the decks to expand and contract in a relatively unimpeded way while providing resistance to lateral loads.

Longitudinal and transverse movements of the deck are accommodated by a large modular expansion joint at each abutment.

Conclusions

To date this is the largest road project in the UK to be procured by Fixed Price Design and Construct tendering.

Balfour Beatty and Scott Wilson Kirkpatrick have worked closely together from the beginning, and between them have developed several innovative design and construction techniques.

The Scottish Office and Strathclyde Regional Council prepared a detailed specification stating exactly what the technical, aesthetic and contractual requirements were; they have had no significant contractual claims to deal with and the job will be completed on time at a fixed cost with little or no conflict between parties.

This has been a challenging project and its successful outcome is a credit to all concerned.