Underbridge 278 Railway Bridge Reconstruction, East Coast Main Line at Newark Dyke

Structural Engineer	**Cass Hayward & Partners**
Steelwork Contractor	**Cleveland Bridge UK Ltd**
Main Contractor	**Skanska Construction UK Ltd**
Client	**Railtrack PLC**

The Newark Dyke rail bridge reconstruction demanded a high profile solution at a strategic river crossing on the East Coast Main Line. Railtrack demanded an aesthetically pleasing solution whilst specifying new high speed design criteria with demanding safety requirements so as not to disturb the live railway.

Steel was chosen by the design and construction team as the ideal structural material on which to base their proposals to secure the Contract. Steel was used not only for the primary features of the new main span, but also for the special substructures and the extensive temporary works, including piling, needed for launching and slide-in operations. Steel's high strength/weight ratio, shallow construction depth, flexibility, durability and robust qualities were essential ingredients in the success of this project.

Two previous bridges had carried the railway on a skewed alignment over the River Trent – the original wrought iron and cast iron trusses constructed in 1852 being replaced by the all steel Whipple Murphy trusses in 1890, one beneath each track, which survived until now. After a series of short-term strengthenings, Railtrack decided to replace the structure and, at the same time, take the opportunity to seek a solution that met their future aspirations for higher speed trains, by increase of the line speed from 100mph to 140mph. The existing double truss bridge involved reverse track curves and hence limited speeds at the site.

The new 77m span bowstring half through bridge is carried on new outboard foundations to avoid uncertainties associated with re-use of the existing abutments. The necessarily heavier new superstructure, with its ballasted track and greater dynamic effects from higher speed trains, was considered likely to give long term safety risks if the existing abutments on timber piles were retained. The bridge itself is square spanning so as to eliminate potential problems with track maintenance and dynamic behaviour. Main bowstring trusses are diagonally braced so as to minimise deformations and are spaced at 11.25m centres to allow the tracks to be re-spaced for higher speed running. The top chord is of open "H" steel plated section offering the maximum lateral inertia for stability whilst eliminating the need for overhead bracings between the trusses and is 1.5m wide and 1.0m deep. Flanges and web are up to 60mm plate thickness and the chord is straight between node points coinciding with a circular arc in elevation giving the best aesthetic appearance.

Water run-off from the top chord is ensured by elimination of stiffening on the top surface of the web. Diagonals consist of fabricated "I" sections measuring 500mm transverse to the bridge with flanges typically 325mm wide. Members of this form facilitate practicable and fatigue resistant welded end connections by elegantly shaped integral gussets to the chords and offer robustness against damage. Screwed rods, wire ropes, strand or hollow sections have been used in bowstring bridges, but were, in this case, rejected due to potential difficulties with compressive capability, durability, fatigue, creep or excessive maintenance of pinned connections. Spacing of node joints is generally 8.46m, but is decreased at the ends for aesthetic reasons and to facilitate rigid U-frame connection to the end three cross girders where the diagonals are of deeper section.

The bottom chord consists of a fabricated plate girder 1.5m deep with its top flange level with top of the floor slab upstand robust kerb. Shear connectors are provided full length of the bottom chord to achieve composite behaviour. At bridge ends the top and bottom chords converge to form a combined stiffened fabrication with downstand to bearing level. Main bearings are of fabricated steelwork and eliminated the necessity for limited life low friction materials. Fixed end bearings are of linear rocker type with roller type bearings at the free end. These bearing types also assist in stability of the bowstring top chords.

The floor is of minimum depth to maintain headroom over the river and is supported by composite cross girders 550mm deep at 2.82m spacing, cranked at the ends to form rigid HSFG bolted end plate connections with the bowstring bottom chord. The floor slab is 250mm thick cast onto GRP permanent formwork and incorporates edge upstands containing the ballast and forming a robust kerb at least 400mm above rail level to meet Railtrack standards.

Two continuous longitudinal steel stringers at 4.0m spacing interconnect the cross girders and serve to distribute concentrated live loadings effectively between cross girders, forming virtually an isotropic floor which fully participates as part of the bowstring bottom chord. This floor configuration enables the calculated acceleration levels to be controlled to the specified limits as demanded by new criteria for dynamic response under higher speed trains.

The solution for the substructures completely eliminated risks involved in excavation beneath the live railway. During a railway possession at Christmas 1999 mined openings were formed through each of the existing abutments which otherwise remained intact to support the existing superstructures. New independent foundations were constructed outside the hazard zone of the railway to receive the ends of prefabricated steel box girder needle beams which were installed through each opening.

Main bowstring girders manufactured and trial-assembled in Darlington were welded up to full length standing upright at site before launching out individually over the river immediately adjacent to the existing live bridge. Transverse slides enabled the girders to be positioned at the correct spacing to receive cross girders which were erected using a purpose-made steel gantry employing the permanent runway beams suspended beneath. Following completion of the deck slab and waterproofing the bridge was ready to be slid into place during the August 2000 Bank Holiday railway possession, which was successfully achieved along with re-alignment of the tracks and erection of new steel overhead electrification masts well within the 72 hours allocated.

Notable features of the temporary works included braced steel plate girder launching beams, one section of which was mounted on a steel barge and fitted into place only during limited blockages of the waterway which otherwise remained open for vessels during the works. The old bridges were slid out on parallel staggered slide paths extending to the opposite bank of the river where demolition took place. These employed the same plate girders which had been used to launch the new trusses across the river. The novel use of steel needle beams as part of the substructures will at a future date assist in removal of the new bridge, thus fulfilling aspirations for sustainable construction.

The new bridge is the first to be completed in the UK which is designed to counteract the dynamic effects of high speed 140mph trains under European based criteria.

Judges' Comment

Railtrack and the Train Operating companies should be proud of the dedication and commitment that the design and construction teams gave to this classic piece of infrastructure renewal. Completed on time and on cost, Victorian and heroic in spirit, contemporary and innovative in execution and design.