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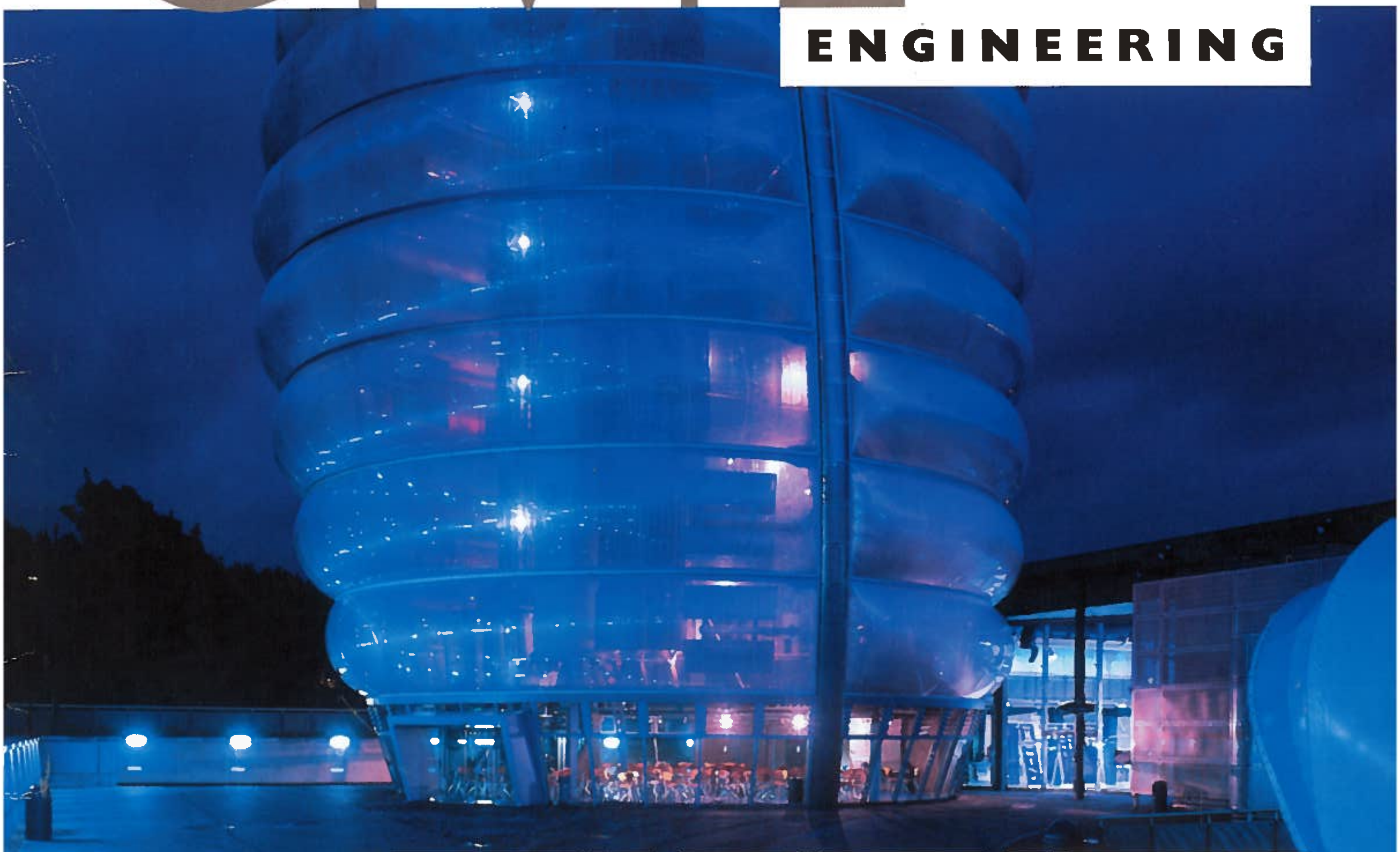

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Float viaduct—a high-speed rail bridge replacement

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The replacement of a strategic bridge at a remote, environmentally sensitive location on the UK's main west-coast railway in just five days required a tremendous amount of advance planning. The 135 year old Float viaduct crossing the upper reaches of the River Clyde needed to be replaced as part of Railtrack's upgrade of the busy route to suit 200 km/h electric trains. Working under a fixed-price design-and-construct contract, Carillion and Scott Wilson opted to move both the old bridge deck out and the new bridge deck in by lifting rather than sliding. Apart from the first span initially refusing to move, the meticulously planned project went without a hitch and was completed well within the five-day track possession.


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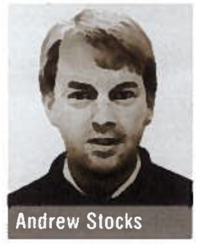
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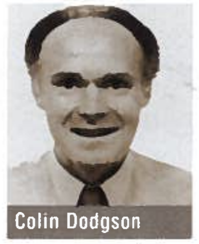
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The Float viaduct carries the UK's electrified west-coast main railway line over the River Clyde near Lanark in Scotland. The original structure, built in 1863, had three simply supported curved steel-truss girders with equal spans of approximately 28 m supported on masonry abutments and cast-iron intermediate piers (Fig. 1). The deck was skewed at 22° and the two sets of piers each have three 2·4 m dia. caissons founded in alluvial deposits in the river bed.

As part of its commitment to upgrade the line, track owner Railtrack promoted a design-and-construct contract in late 1998 to procure a modern bridge, capable of carrying high-speed trains travelling at up to 200 km/h. The conditions of contract were the Institution of Civil Engineers' *Design and Construct Conditions of Contract*[1] supplemented by Railtrack special conditions.

The client's brief required the existing bridge to be removed and a new structure erected during a five-day closure of the track in early October 1999. The possession had been agreed previously between Railtrack and the train operators, and could not be changed—any overrun would attract significant financial penalties for the contractor.

Three contractors were invited to tender and, following assessment of the bids, a £3·25 million fixed-price contract was awarded to a consortium of Carillion Construction (constructor) and Scott Wilson (designer) in March 1999.

A remote and natural setting

The site is located in a rural area south east of the village of Carstairs Junction in South Lanarkshire, Scotland (Fig. 2). Access is difficult, particularly through the village, owing to the narrow twisting minor roads and a 3 t weight limit on an adjacent road bridge. Furthermore, the route from the road to the banks of the river is across agricultural land.

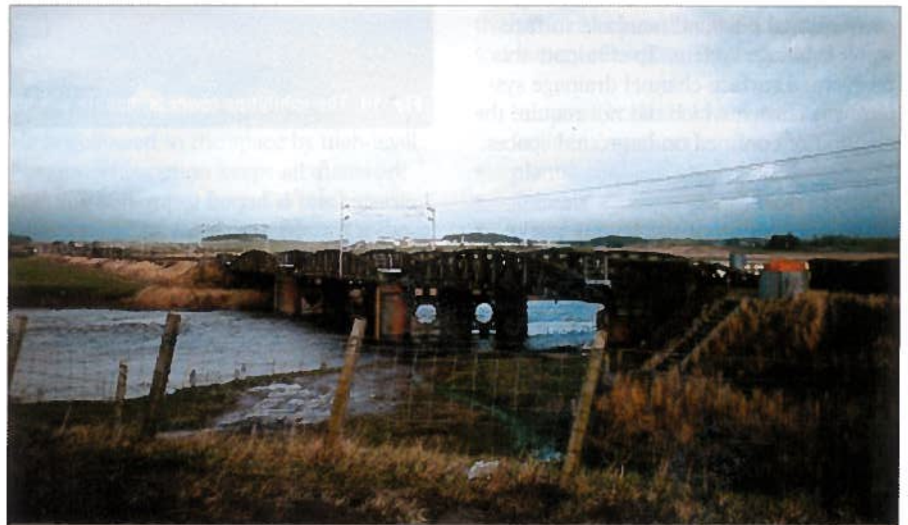

Fig. 1. The three steel trusses of the original Float viaduct over the River Clyde were built in 1863 on cast-iron piers and masonry abutments

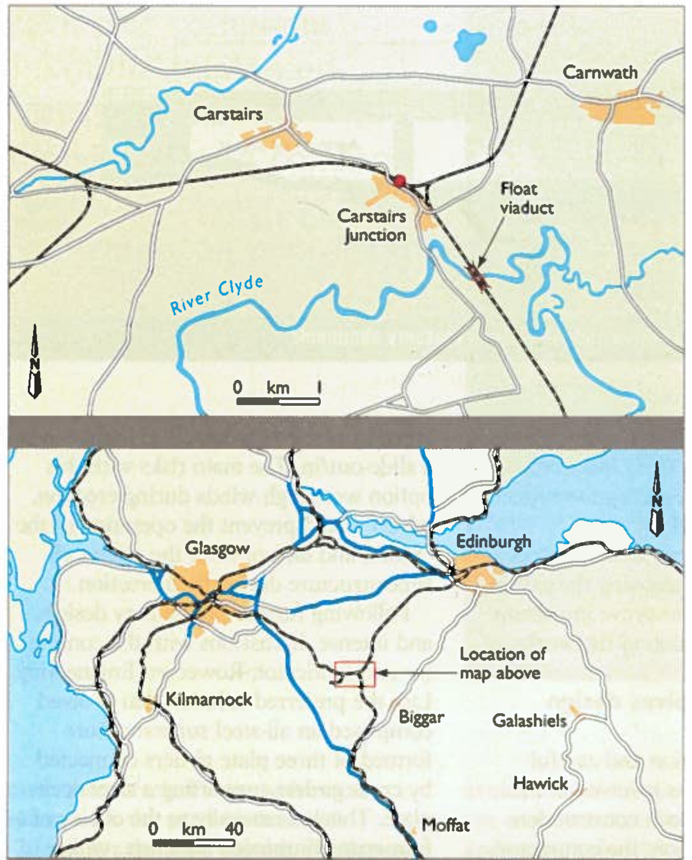

Fig. 2. The Float viaduct carries the UK's main west-coast railway across the upper reaches of the River Clyde

The Float viaduct forms the downstream boundary of the Clyde Meanders area, which is designated as a 'site of special scientific interest'. This section of the river has a highly unstable flow regime, evidenced by the changing position of the main channel over the years. The river has a history of flooding but, under normal conditions, the river is approximately 40 m wide and is gently flowing apart from the main channel, which currently lies adjacent to the north bank.

The brief required that the proposals for a new bridge had to avoid any damage to the river and the local environment. In addition, the visual impact of a replacement structure was an important consideration, which required the tenderers to take full account of the setting and provide a positive feature within the surrounding landscape.

Prior to tender, Railtrack had commissioned a full site-investigation, the results of which confirmed that the ground conditions at the site are poor, consisting of alluvial deposits to depths of up to 26 m.

Re-use of existing supports considered

With the specific requirements and constraints of the site in mind, several possible solutions for the replacement structure were apparent. The contractor investigated the most appropriate structural forms, particularly with regard to the method of removing the existing bridge and erecting the new superstructure.

From an early stage, it was clear that due to the specified short construction period and the very poor ground conditions, steel—with its attributes of rapid erection and relatively low weight—was an obvious choice of material for the superstructure. In addition, a shallow construction depth was required to ensure adequate clearance above the maximum flood level. A 'half-through' form of deck construction—the deck being located within the lower half of the plate girders—was thus considered essential.

Initially, serious consideration was given to keeping the existing masonry abutments and cast-iron piers, with only the existing superstructure being replaced. However, it was soon apparent that the precise details and integrity of the capping arrangements at the top of the caissons could not be confirmed until the existing deck had been removed. In addition, continuity of the new deck would increase the vertical reactions on the existing piers.

Furthermore, difficulty was encountered in demonstrating how the existing substructures could resist the large longitudinal forces due to traction and braking of trains travelling at 200 km/h despite the use of load-sharing devices. Therefore, despite the obvious attraction of obviating the need for major new substructure works, the team concluded that the technical and programme risks were too great and this option was abandoned.

Determining the erection method

Having established that new foundations were necessary, the span arrangements, form of deck construction, and type and location of supports had to be determined—all of which were heavily influenced by the method chosen for removing the existing deck and erecting the new deck.

For railway bridges such as the Float viaduct the method of erection normally adopted is to construct a new superstructure next to the existing bridge, on pre-constructed slide-paths, and then roll or slide it into position when the existing structure has been removed. On this basis, a continuous three-span bridge solution was developed. It had twin steel longitudinal girders with cross girders supporting a concrete slab, which would be slid into position on prepared slide walls. The existing structure would have been previously removed to the opposite side of the crossing, also sliding on purpose-built temporary walls or trestles.

> to reduce the extent of the temporary works constructed in the river, the contractor investigated the feasibility of removing the existing superstructure using a large mobile crane instead of a slide-out

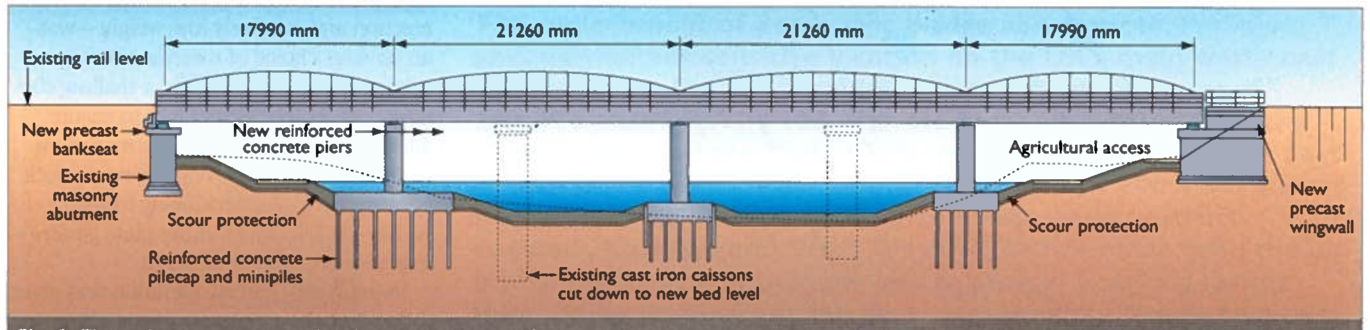

Fig. 3. The replacement structure has four steel spans resting on new concrete piers and the existing masonry abutments

However, at this particular site, the cost, environmental impact and programme implications of building substantial piled slide walls in the river represented major disadvantages.

So, in order to reduce the extent of the temporary works constructed in the river, the contractor investigated the feasibility of removing the existing superstructure using a large mobile crane instead of a slide-out. It was quickly established that cranes of the required capacity were available and could access the site, which, in turn, raised the possibility that the same crane might also be used to erect the new superstructure in sections providing they were sufficiently lightweight.

Not only did the use of a crane remove the need for slide tracks, it also maximised the time for designing the superstructure and for fabricating the steelwork. Furthermore, it offered speed and flexibility when removing the existing deck, a fact that was to prove important later during construction of the works.

Lifting option resolves design choice

After much discussion and careful assessment of the risks involved in the alternative forms of deck construction and methods of erection, the contractor chose to use large mobile cranes for both the removal of the existing deck and the erection of the new structure, rather than a slide-out/in. The main risks with this option were high winds during erection, which would prevent the operation of the cranes, and lack-of-fit of the steelwork superstructure during final erection.

Following further preliminary design, and intense discussions with the contractor and fabricator, Rowecord Engineering Ltd, the preferred solution that evolved comprised an all-steel superstructure formed of three plate girders connected by cross girders supporting a steel deck plate. This led naturally to the choice of a four-span continuous structure, which enabled the new intermediate supports to be positioned in optimum locations remote from the existing piers (Fig. 3). A further advantage of this arrangement was that it enabled loading on the existing masonry abutments to be reduced, allowing them to be retained as part of the final scheme.

The detailed design of the new structure was undertaken in accordance with the requirements of BS 5400,[2] including the proposed draft amendments to part 3, supplemented by Railtrack's current *Group and line standards*.[3]

The new superstructure is of half-through construction and has three continuous steel-plate girders with skew spans of 19 m, 22 m and 19 m. These are connected by transverse beams supporting a steel deck plate, which in turn carries the ballast and track (Fig. 4). The deck is skewed at 22° to the supports. Access walkways are cantilevered from the outer girders and are provided with a cosmetic arch feature to replicate the appearance of the original curved truss girders.

The main girders are a constant 2 m deep and are spaced approximately 4·1 m apart transversely. Flange widths are 540 mm for the outer girders and 720 mm for the centre girder. Thickness varies from 45 mm to 60 mm on the outer girders and 35 mm to 55 mm on the centre girder. Web thickness is constant throughout the length of the bridge, being 15 mm and 20 mm for the outer and inner girders respectively.

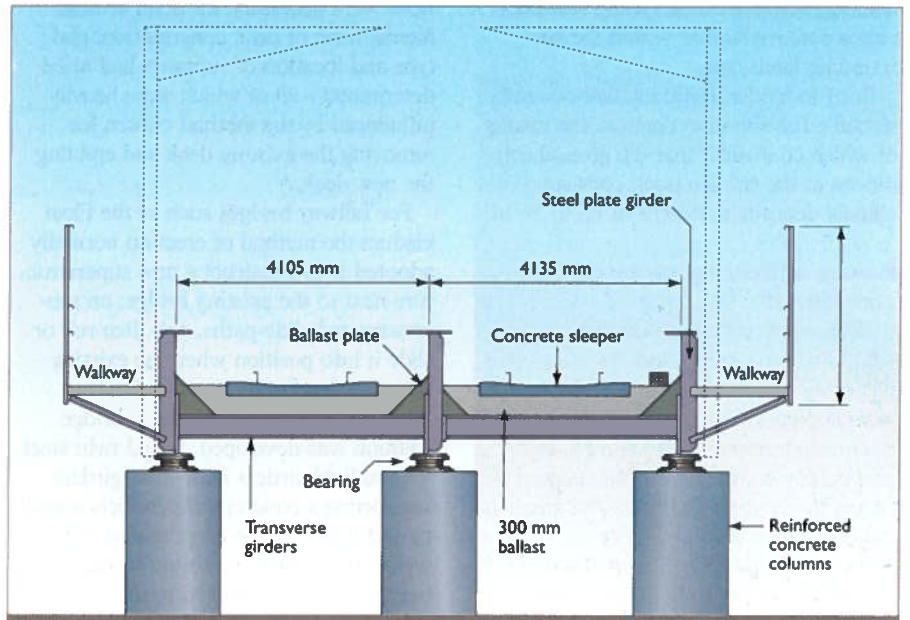

Fig. 4. The three main steel plate girders are 2 m deep

> Each pier comprises 1·5 m dia. reinforced concrete columns supported on a common reinforced concrete pile cap resting on mini-piles

Fig. 5. New piers sit on clusters of mini-piles that were installed under the existing bridge deck

Designing for fatigue and derailment

Transverse beams, which are skewed to the main girders and spaced at approximately 600 mm centres, are generally inverted 229 x 305 rolled structural tee sections apart from at support locations, where a fabricated tee is required. The 30 mm thick deck plate is welded to the web of the transverse beams, thus forming the top flange of the member.

Every third transverse beam, including those at the supports, is rigidly connected to the outer and inner girders carrying the down-line track. This provides a U-frame restraint to the compression flanges of the main girders. On the up-line track, the transverse beams are only connected rigidly to the outer girder, being pinned to the central girder. This restrains the outer beam by L-frame action. The arrangement avoids the risk of premature fatigue failure at the intersection of the main girder and cross girder. All other transverse beams are connected by patch plates to the main girder webs and transfer shear forces alone. The connections were made using 22 mm or 24 mm dia. tension-control bolts for speed of completion.

Additional stiffeners were added to the central girder to enable the bridge to remain operational in the event of localised damage caused by a train derailment. Provision had also been made for the replacement of the bearings by jacking of the superstructure from the substructure.

The steel for the main girders was grade S355 J2 G3 to BS EN 10025,[4] whereas the transverse girders and deck plate were grade S275 J2 G3. The provision of adequate construction tolerances and 'fit-up' of the steelwork were fundamental to the success of the project. Therefore, every opportunity was taken in the design and fabrication process to achieve the tolerances specified in part 6 of BS 5400. Measures taken included the careful detailing of all joints and a trial erection of the completed steelwork with match drilling of the bolted splice connections. For positioning of the deck on the substructures, a tolerance of 50 mm in all directions was built into the design; even the movement-joint cover plates were made in alternative sizes to provide the necessary tolerance.

Reducing horizontal loads on abutments

The viaduct is carried over the River Clyde on new piers and the existing masonry abutments. Each pier comprises 1·5 m dia. reinforced concrete columns supported on a common reinforced concrete pile cap resting on mini-piles. To form the new abutments the upper section of the existing masonry structures was removed during the main possession and then capped with a new interlocking precast concrete plinth and wing walls, forming a robust U-section in plan.

The girders are supported on pot-type bearings bolted to bearing plates, which in turn are bolted to their bottom flanges to minimise fatigue problems.

The bridge is fixed at one of the piers adjacent to the abutments to resist the large longitudinal forces due to braking and traction of the 200 km/h trains, together with other coexistent horizontal loads. The other two piers are provided with a longitudinal guided bearing, where-

Fig. 6. The first span of the existing bridge deck being lifted out by a 900 t mobile crane during the five-day possession


Fig. 7. The first 120 t span of the new bridge deck being lifted in by a 1000 t mobile crane, complete with bearings and walkways

as at the abutments the bearings are free to slide in all directions. This arrangement was chosen not only to reduce horizontal loading on the existing abutments but also to provide maximum tolerance during erection. Longitudinal movements of the deck are accommodated by a simple plated expansion joint at each abutment.

Piling and steel fabrication starts

The first operation on site was to build a substantial haul road to both the north and south sides of the river for delivery of the cranes and the new deck sections. Next, temporary scour protection was placed around the existing piers. The permanent scour protection—a 200 mm thick granular filter layer topped with a minimum 700 mm layer of rip-rap—was constructed in sections immediately following the completion of the viaduct.

Temporary bunds were constructed in the river to provide access for the piling operations. Reinforced concrete mini-piles formed within bottom-driven steel casings were chosen, as they do not remove material from the ground and they produce relatively small vibrations. This enabled the piling operations to be undertaken beneath the existing structure while maintaining normal railway operations. Furthermore, the system avoided any potential environmental problems within

> "The first new deck section was then erected onto the new substructure using a 1000 t mobile crane"


Fig. 8. New track being laid on the new bridge deck


Fig. 9. Trains running at up to 200 km/h started using the new viaduct immediately after the five-day possession

the river regime and adjacent site of special scientific interest.

During the piling operation, a random layer of cobbles was encountered approximately 10 m beneath ground level, which had not been identified by the site investigation. The cobbles caused a number of the casings to 'hold-up' or deviate so badly that they split and had to be abandoned. The problem was resolved quickly by welding strengthening strips to the sides of the caissons and by increasing the size of the concrete driving plug. Also, two of the pile caps had to be increased in size in order to accommodate the replacement piles.

On completion of the piling operations, the reinforced concrete pile-caps and columns were constructed within sheet-piled cofferdams, all work having been undertaken without disruption to the operation of the railway (Fig. 5). Simultaneously, the new capping plinth and wing-wall sections for the abutments were precast adjacent to their final location ready for installation.

The steelwork, valued at £1 million, was fabricated by Rowecord at their works in Newport, South Wales. A full trial erection was undertaken to ensure an accurate fit on site. On completion of the steelwork, a glass-flake epoxy-paint protection system was applied at the works before dismantling for transportation to site.

Once on site, the steelwork was reassembled into four sections—complete with bearings, ballast plates and walkways—in a designated area adjacent to the south abutment. The top surface of the steel deck plate was waterproofed with a liquid spray-applied system, which was then covered with protective boards. The weight of the sections varied from 120 t to 170 t.

Possession—five critical days

At the start of the main five-day possession of the line, the overhead line equipment was slewed clear of the existing bridge and the track and ballast were removed. Starting at the south span, the existing superstructure was then connected to a 900 t mobile crane ready for removal.

Initially, the crane was unable to lift the span clear of the pier support. The bottom flange of each girder was then cut locally to allow the span to be lifted clear (Fig. 6). Subsequent inspection of the area, which had previously been inaccessible, revealed that the problem was caused by steel wedges down the sides of the bearing shoes causing 'lock-up'. The remaining spans presented no further unexpected problems and the delay to the programme was soon recovered. All spans were removed to a designated demolition area where hydraulic shears quickly dismantled them, the same machinery being used to demolish the existing caissons.

With the deck removed, work started on the abutments. The existing masonry was reduced in height, the new precast sections were craned into position and connected together, new drainage was installed and, finally, backfilling was completed.

The first new deck section was then erected onto the new substructure using a 1000 t mobile crane (Fig. 7). When the span was positioned correctly, the bearing bottom spreader plate at each of the supports was welded to a steel bearing plate, which had been previously bolted to the substructures. This procedure was repeated for the remaining spans, each deck section being connected to the preceding one with bolted splices between the adjacent girders and deck plate.

Finally, the deck joints, new ballast and track were installed (Fig. 8) and the overhead line equipment was connected to new masts on the deck. The structure was completed and the line was ready for reopening well within the five-day possession (Fig. 9).

Conclusions

The Float viaduct is one of the first major railway bridges procured by Railtrack in Scotland using fixed-price design-and-construct tendering. The client, the contractor and the designer worked together closely from the beginning on a difficult and demanding project. Regular design team meetings chaired by the client helped to ensure progress was maintained and that potential problems were ironed out in advance.

The successful outcome of the project is a credit to all concerned.

Acknowledgements

The project team and their roles was as follows:

- Railtrack—client
- Carillion Construction—constructor
- Scott Wilson—designer
- Cass, Hayward and Partners—independent checker
- Rowecord Engineering—steelwork fabricator.

Photographs are courtesy of Owens Industrial and Commercial Photography and the National Railway Museum, York.

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