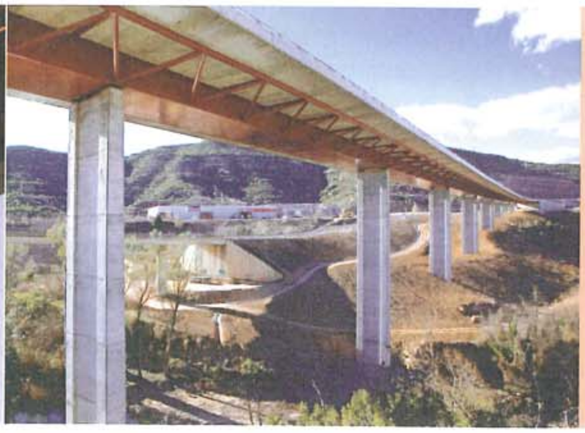
MODESTY PREVAILS

A new road bridge in Spain demonstrates how demanding criteria can inspire a pleasing solution, even at a modest cost, according to **Peter Tanner** and **Juan Luis Bellod**



Far left: View of bridge deck soffit and pier showing convex surfaces

Left: Partial view of the finished bridge

Photos by Paco Gómez

Last December saw the completion and opening to traffic of a new viaduct over the Llobregat River at Puig Reig in Spain. This bridge illustrates how even the most demanding conditioning factors can inspire a satisfactory solution. The functional design that was adopted, characterised by the simplicity of its lines, was enhanced by the careful shaping of structural members and good detailing. The modern, technologically-advanced bridge design is compatible with an elegant solution which meets the most exacting aesthetic standards, with no need for inefficient members or adornments and at an affordable additional cost above the cheapest solution.

The new bridge is part of a scheme to improve the motorway C-16 in Catalonia, between Puig Reig and Berga, and shorten the driving time between Berga and Barcelona by more than half an hour. This involved spanning the Llobregat River with a sizeable viaduct not far from Puig Reig.

With the widened layout of the motorway, the total length of the viaduct comes to more than 550m. In plan it is straight along most of its length but curves as it nears the abutment on the Berga side, where the sharpest radius is 600m. In elevation, the bridge slopes gently on a grade of 1.4%. Its single deck carries four lanes of road traffic, two in each direction, four service lanes and the median, and has a total width of 23.8m.

Environmental restrictions meant that no temporary supports could be erected near the Llobregat River during construction, nor were heavy cranes allowed into the same area.

In most structures, economic constraints play a decisive role in the adoption of the final solution, and the Llobregat Viaduct was no exception. Nevertheless, in view of the location of the bridge and its visibility from the nearby town, the owners also wanted a landmark structure with a simple and well-balanced design. All these constraints made it particularly important to strike an optimal balance between economy and aesthetics.

A continuous nine-span structure with a total length of 568m was devised for the bridge deck. Topographic considerations led to the two end spans being 60m long, while each of the seven inner spans is 64m long. Despite the unfavourable outer to inner span length ratio of 0.93, this solution was preferred to other possible layouts with shorter spans,because it enhanced the visual efficiency of the design. Two of the most important determinants of elegant bridge design are transparency and slenderness: bridges are often regarded as elegant when characterised by the efficient use of construction materials in solutions with generous span lengths.

The bridge girder is a composite member consisting of an open, 6m-wide steel box and a concrete slab. In the area around the internal supports, the bottom flange of the box girder is also composite for greater hogging bending strength and system ductility. With a steel section height of 2.55m, the inner spans have a slenderness ratio of 25. Visually, the slenderness effect is heightened by cantilevering the concrete slab 8.9m on each side of the steel box.

The cantilevers are supported 3.5m from the edge by longitudinal chords attached to spatial truss girders, which in turn are connected laterally to the steel box. In addition to the chord, each truss consists of inclined diagonals and horizontal ties. In elevation, each set of two diagonals, made of 323mm-diameter hollow sections, forms a v-shape. Both the ties, which are at right angles to the bridge centre-line, and the longitudinal chords, are composite members, consisting of open, concrete-filled oval shapes connected to the deck slab. The slab itself consists of 80mm-deep precast concrete slabs covered with in situ concrete to the total slab depth, which varies from 180mm at the edges to 340mm over the longitudinal chords. The total slab depth over the 6m-wide box girder is 240mm.

Along the chord, the diagonals are spaced at 8m centres, as are both the horizontal ties that connect these joints – between the chord and the diagonals – to the box girder, and the connections between the diagonals and the bottom of the steel box. Because of the slant of the diagonals and their layout, the trusses not only transmit loads from the cantilevers to the box girder, but form part of the overall resistance mechanism of the deck, reinforcing the stiffness and strength of the composite girder. At the same time, the truss design is visually attractive.

The cheapest solution would have been to use prefabricated concrete girders, with a shorter span length of about 40m, but this solution was ruled out by the owner because it did not create the visual impression that was required in this location. The saving this would have made on the US$19 million contract cost was estimated at just 15%.

Each concrete column has two 1.3m-wide shafts which are spaced at 4.7m centres and connected by a concrete wall with convex surfaces, creating a single monolithic member 6m wide. The column depth is variable, tapering slightly to 1.4m at the top. It is to these cross-sectional dimensions and their height of up to 43m that the columns owe their slender elegance.

Special attention was also paid to the good detailing that is essential to ensure appropriate member performance, including correct load transfer mechanisms, sufficient fracture toughness, fatigue resistance and durability. Good detailing can also significantly affect the visual impact of a bridge and the following solutions were adopted.

Despite the complexity of the multi-element connection details, the load transfer mechanisms were kept as simple as possible. Connection devices were placed where they could act most effectively, resisting shear rather than tensile stress and stress concentration was avoided as far as possible, adopting smooth transitions between elements with different cross-sections.

Details were designed to be compatible with simple manufacturing methods to contribute to improving the quality of workmanship and reducing the risk of imperfections.

Once the abutments and the columns had been erected, the steel box girder was lifted into place by cranes on seven out of the nine spans, starting at the abutment on the Berga side. Temporary supports were set as close as possible to the centre of each span during this stage of construction to reduce span lengths. Since no such procedure was allowed alongside the Llobregat River, the structure had to be launched from the southern abutment across the first two spans, which included the river span. A 12m-long launching nose was used for this operation to mitigate the effects of actions during this stage and eliminate the risk of patch loading-induced instability. The precast concrete slabs were then laid in place. Finally, the in situ concrete was poured and the temporary supports were removed.

An elastic-plastic design procedure was deployed to ensure bridge structural safety both during and after construction. Given that its flexibility meant system deformation would depend on how the construction stages were defined, action effects were calculated in accordance with elastic theory, taking account of system evolution throughout. On the basis of the results, the bridge girder was precambered to offset the deformation due to self weight, permanent loads, creep and shrinkage ■

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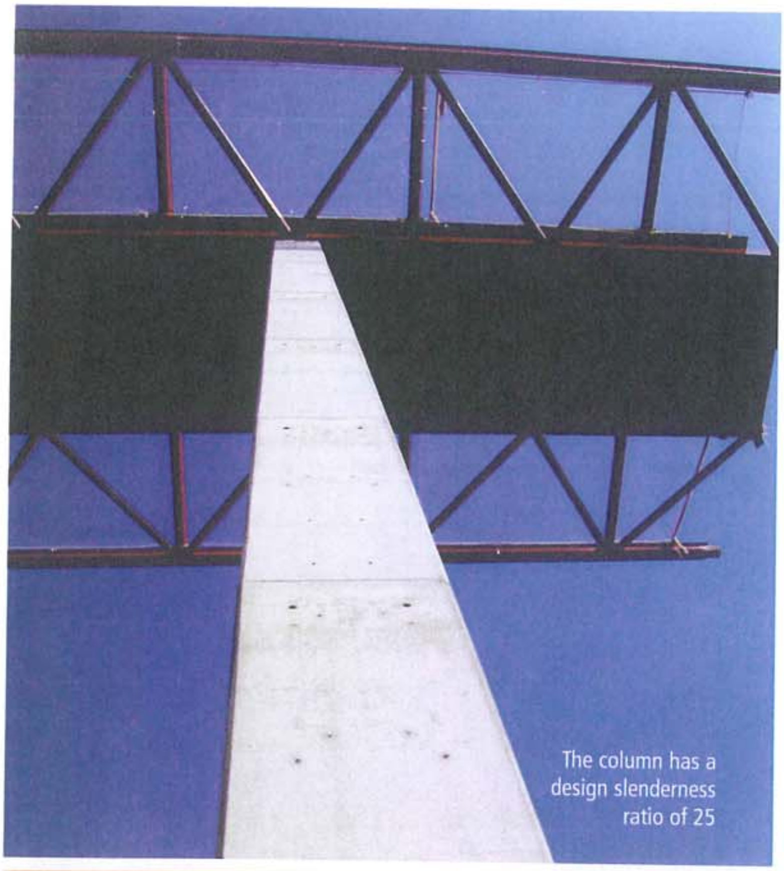
The column has a design slenderness ratio of 25

Owner: Gestió d'Infrastructures SA
Structural engineer: Cesma Ingenieros
Main contractor: Joint venture FCC/Comsa/Copcisa/Copisa
Steelwork subcontractor: Iturmo
Launching subcontractor: BBR Pretensados y Técnicas Especiales