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Seismic Protection of the Guadalfeo Bridge by Viscous Dampers

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Summary

The Guadalfeo bridge is a continuous 5 spans - 585m long deck steel truss bridge located in the mountain region of Grenada on the A-44 Sierra Nevada Highway in Spain.
The deck of the bridge is 10.35 m high and 24 m wide, and the cross section of the girder is made of 5 main beams: three on the upper level and two at the bottom. Nodes of the truss are each 10 m apart and the diagonals connecting each node have circular hollow sections (CHS). On the top of the truss a concrete slab 30 cm thick is placed. The piers height ranges from 24m to 85m.
The bridge is located in a region prone to earthquakes and has been designed to withstand seismic actions characterized by a Peak Ground Acceleration of 0.226g.
Under this condition, a conventional bridge bearing system composed by fixed and sliding pot bearings was not preventing from very large deck displacements and pier deflections. Thus, two design alternatives have been investigated, the first solution considered for shock transmission units connecting the deck to the abutments whilst the second one used viscous dampers at the same locations.
The designer opted for the second solution being able to obtain an optimum control of both deck displacement and seismic loads on piers and foundations.
The utilized viscous dampers are characterized by a 3000kN capacity, ±300mm stroke and a 0.15 damping exponent and are installed in group of five units at each abutment.
The paper aims at providing a description of the design concepts with a particular attention to the seismic design and to the full-scale testing activities on viscous dampers performed at FIP Industriale laboratory in Italy.

1 INTRODUCTION

1.1 Location

Road N-323 crosses the said Guadalfeo river near the toes of the Mount Veleta, one of the highest mountains in Spain, where very special conditions of the surroundings can be found, such as:

- The area around Granada is a geologically active area with definite tectonic activity. In Spain a statically equivalent action can be used as an approximation of the dynamic effect produced by seismic actions. In doing so, the code proposes for this area a design acceleration equalling 0.22g.
- A bridge was proposed to be located where the Guadalfeo and Izbor rivers meet. As a consequence, some 15 to 20 m thick alluvial deposits are found. So, a deep foundation using in-situ piers was proposed for the main spans.
- Furthermore, there are some active large landslides on the vicinity of the southern abutment, because of the tectonic activity.
- Central piers are expected to be 90 to 100 m high. The distance between both valley slopes results 600 m, approximately.
- The construction of a new dam is undergoing 2 km down the river from the site of the proposed bridge. So, in the future the depth of the water will reach 60 to 70 m deep near the bridge.

1.2 Design criteria

During the preliminary design phases different solutions were considered, but only medium span bridges were selected because of the foundation conditions, using spans 80 to 170 m long. The number of piers was scarce, as the needed deep foundation did not reach unreasonable proportions. Arch bridges, cable stayed bridges and suspension bridges were eliminated because of foundation conditions.

Considering seismic resistance, the material of the deck was analysed. Steel girders were preferred to prestressed concrete girders: concrete decks are approximately 200% heavier than composite girders, and therefore seismic effects are double.

Finally, the existence of a 60 to 70 m deep water body during the construction of the deck was to be taken into account. Different construction methods were studied in connection with selected typologies of the deck. Among them, cantilever construction using temporary wires and launching of the deck were examined.

2 BRIDGE DESCRIPTION

2.1 Horizontal and vertical alignment

The bridge over the Guadalfeo river is a five span bridge with a total length of 585 m. Its platform is 24 m wide, holding a dual carriageway with two lanes in each direction.

The horizontal alignment is a very gentle curve, with a radius of 17200 m. Near the northern abutment there is a transition. The cross slope is 8% near the northern abutment; due to the slightly curved horizontal alignment, a cross slope of 2% is used in the rest of the deck.

Concerning the vertical profile, nearly all the deck is placed on a slightly descending alignment sloped 0,20 %. The maximum distance from the upper level of the deck to the ground is about 100 m.

Abutments reach a height of 20 m on the Northern access and some 15 m on the south slope.

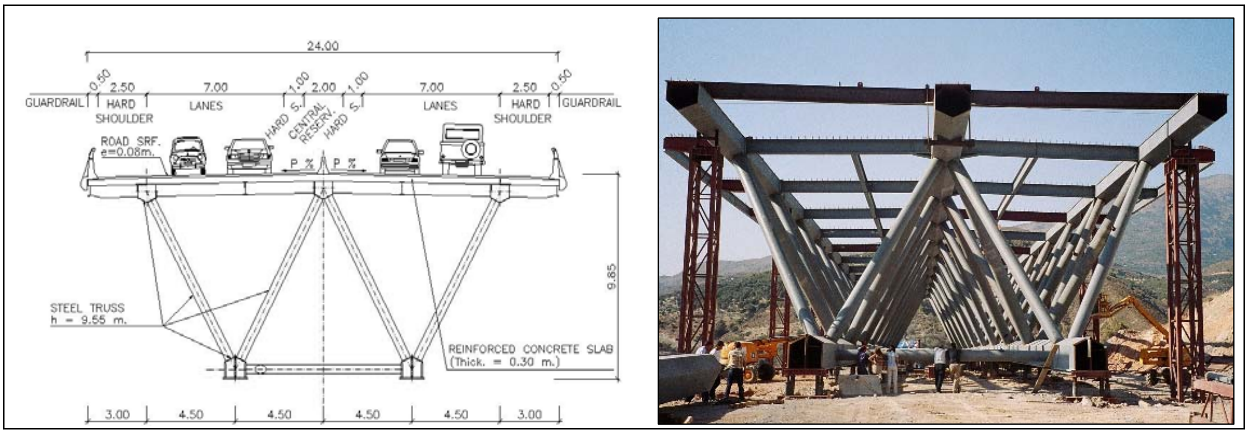

Figure 1: Cross section of the deck.

2.2 Deck

The proposed bridge is a composite truss 585 m long. The deck is a 5 span continuous beam. Spans are 85+140+140+110+110 m.

The cross section of the steel truss is 9.55 m deep. The truss is made of three main beams on the upper level and another two lower main beams. The distance in between main beams is 9 m. The cross section of each bar of the upper level is made of five plates 1000 mm deep and 950 mm wide. Its shape is pentagonal to optimise junction between main beams, transverse beams and diagonals. The cross sections of the two main beams of the lower chord are similar to the above mentioned beams of the upper level, but 1200 mm deep and 1280 mm wide. Additionally, inclined plates were located close to the connection between the webs and the lower horizontal plate. In doing so, a closed partial section was created to distribute the concentrated load from temporary bearings during launching to the webs. By doing so, patch loading effects were diminished. The thickness of webs varies from 15 to 50 mm. Thickness of horizontal plates of main beams varies from 15 to 60 mm.
Groups of four diagonal bars are used for connecting the main beams of the upper level to those of the lower level, with nodes distributed each 10 m. Each diagonal is a circular hollow section (CHS). Their diameter goes from 406 to 609 mm and their thickness is between 6.3 and 35 mm.

Secondary beams are located parallel to main beams of the upper level. An I-shaped section 600 mm deep was proposed. The connection of these longitudinal beams to the main beams is made using transverse I beams located each 10 m.

Therefore, a girder measuring 10 x 9 m is made by longitudinal secondary beams, main beams of the upper level and transverse I beams. On the top of the girder a reinforced concrete slab 30 cm thick and 24 m wide is placed. Nominal resistance of the on site poured concrete is 30 N/mm^2.

The steel grade for all beams, CHS´s and auxiliary elements is S355 (fy = 355 N/mm2).

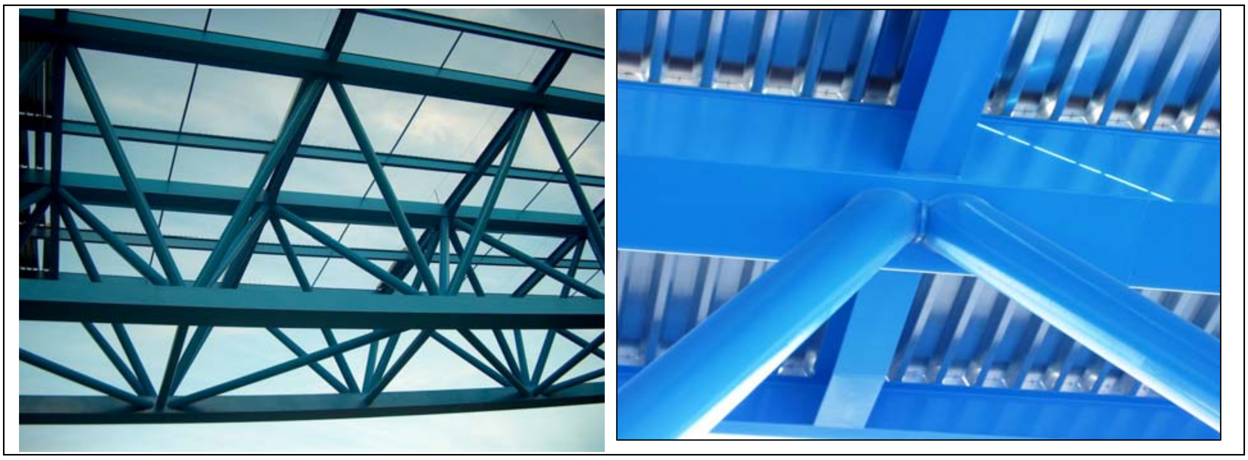

Figure 2: General view of the steel truss and connection of the main beam of the upper chord with main diagonals.

2.3 Substructure

Piers are made of reinforced concrete with a compression strength of 30 N/mm2. Their cross section is a hollow section measuring 4.5 x 12.0 m at the top. Their transverse dimension increases 2.5% all along the pier, reaching some 16.5 m on the base of pier P3, which is 90 m approximately high. The wall thickness of the piers is 35 to 40 cm. The lower part of the pier is made of a stand with pyramidal shape, constituting a transition from the pier itself to the pile cap, which measures 28x12x3 m. The deep foundations of pier P2 and P3 are made by 17 concrete piles 2 m in diameter, whereas the foundation of piers P1 and P4 are made with 14 piles 2 m in diameter. As it has been mentioned, the piles cross a thick layer of alluvial deposits until the rock layer is reached. The longest piles are 31 m long.

The abutments are made of on site poured 30 N/mm2 reinforced concrete. The northern abutment is 23 m tall. Foundation of both abutments is directly on superficial layers of adequate resistance.

As mentioned above, seismic effects equivalent to 0.22g are to be considered in the design and calculations. So, seismic devices were proposed. The two main goals of this design were:

- Eliminating longitudinal loads from the top piers.
- Diminishing global seismic effects to adequate limits.

In order fulfil these two conditions, seismic dampers were proposed. Detailed dynamical calculations were performed for evaluating the forces to be considered for different nominal velocities. Maximum target load was fixed to 15.000 kN per abutment and maximum allowed movement was considered to be + 300 mm.

2.4 Proposed method of construction

The highest pier is approximately 90 m. So, sliding formwork was used for erecting all.

As mentioned above, it was supposed that water will be flowing underneath the structure before the construction of the deck could be initiated. So, it was proposed to launch the deck. When preliminary calculations were made, a 2000 mm deflection was estimated on the tip of the truss. In order to decrease this high deflection, a temporary tower 40 m high was considered. This tower was balanced by two sets of cables with an adequate strength to resist a load of 22000 kN. In doing so, the maximum vertical deflection was reduced to 850 mm and loads on diagonals and main beams during launching were also reduced. It was not feasible to launch the first span near the north abutment due to its geometry. Additionally, access to the site was possible. So, normal construction was proposed for this first span, erecting steel structures using temporary piers and placing parts of the steel structure with cranes.

Figure 3: General view during erection of the steel truss on the access to the South abutment

Figure 4: General view while launching

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