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A Covered Double Decker Pedestrian Bridge in Parma

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Abstract

The new Europa Bridge, currently under construction in Parma, Italy, is composed of two distinct structures: a road bridge and a covered pedestrian bridge. The road bridge is a three spans continuous bridge, with a mixed steel-concrete structure. The covered pedestrian bridge encloses a two level hall, which shall be used as an exhibition centre. This paper presents the main concepts at the basis of the structural lay-out.

Keywords: Covered bridges, conceptual design, structural analysis, seismic analysis

1. Introduction

The new Europa Bridge, currently under construction in Parma, Italy, is composed of two distinct structures: a road bridge and a covered, double decker pedestrian bridge (Figure 1). The two bridges differ for both function and bearing scheme. The road bridge is a three spans continuous bridge with a mixed steel-concrete structure. The typology is quite usual, although the constraints posed by the hydraulic clearance and by the road track lead to a very slender deck.

The covered pedestrian bridge encloses a two level hall, which shall be used as an exhibition centre. The volume enclosed is a segment of a torus, whose axis in the horizontal plane is determined by the road track curvature. The bubble section which enwraps and covers the passage creates a strong volumetric impact which radically differentiates the structure from the traditional image of a bridge. Formal and structural choices were made coherent by selecting pre-defined shapes capable of the desired static performances, so that the two aspects became functional to one another. The definition of the bearing

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structure took advantage of the need of distributing the structural material at different levels, by assuming their relative distance as the depth of a truss beam. Thus, the bearing scheme resulted in a lattice structure in which the two planes work as chords in tension or compression; in the side planes, the two chords are connected by means of bracings which bear the shear actions.

Figure 1: Architectural impression. Perspective of the south front of the pedestrian bridge.

2. The Covered Pedestrian Bridge

2.1. Geometrical and functional characteristics

The volume enclosed by the superstructure of the pedestrian bridge is a segment of a torus, whose axis in the horizontal plane is determined by the road track curvature. The three spans are 36, 45 and 36 m respectively. The bubble has a strong volumetric consistency, generated by the surface which encloses the bridge, as shown in Figure 1.

Although several examples of pedestrian bridges intended as crossings, panoramic viewpoints, exhibition and shopping areas are known, the wide spaces which characterize the Parma Europa Bridge single it out as a very peculiar object.

During the design process, the first problem to be dealt with was the concept of the main bearing structure. Such a choice had to consider the width of both the road and the pedestrian decks, and subsequently their self-weight, the intensity of the live loads and the spanning among piers and abutments.

Given the fact that the total amount of structural steel was destined to be distributed on two different horizontal planes, 8 m apart, the basic idea was to take advantage of this distance and consider it as the depth of a truss beam spanning over the Parma river.

2.2. Conceptual design. The general layout

The pedestrian bridge was conceived as a truss beam (Figures 2, 3.b). The bearing scheme resulted in a lattice structure with an upper and lower chord working in tension or compression. In the side planes, these two chords are connected to one another by means of bracings, tilted at an angle of about ±60°, so that each side is subdivided into triangles. These elements are intended to bear the shear actions, and are arranged so as to converge to the bearing supports placed on the piers and on the lateral abutments. The surfaces defined by the lateral bracings follow the curved shape of the road track (Figure 2).

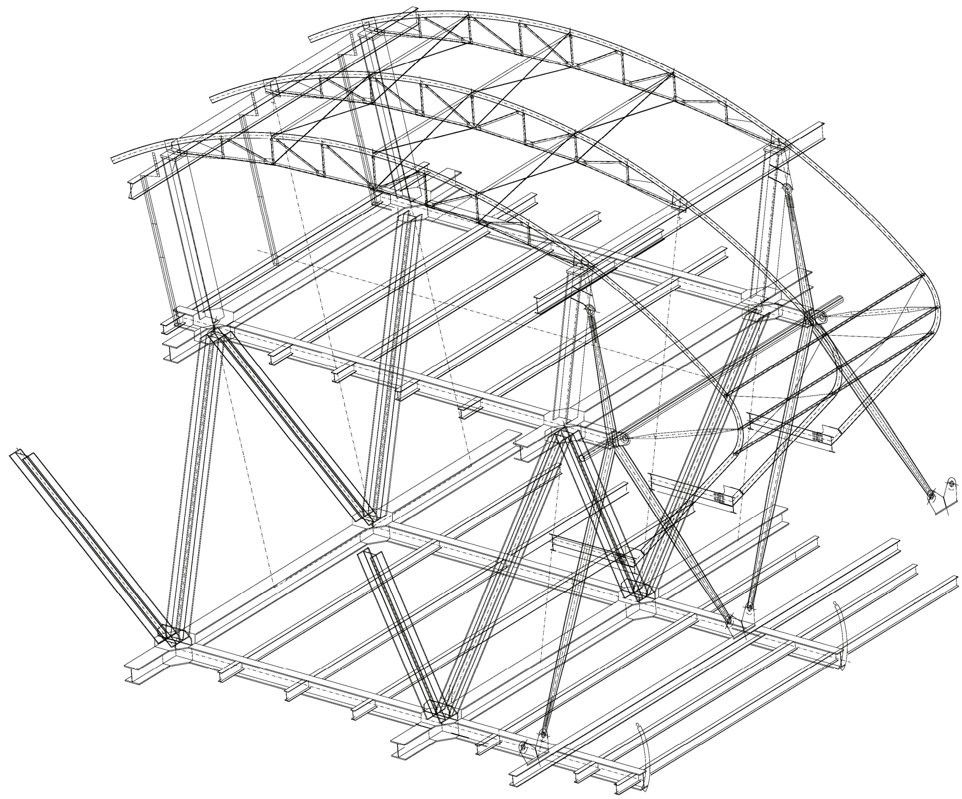

Figure 2: Isometric view of a typical segment of the pedestrian bridge.

In each chord, the two main longitudinal beams are connected to one another by a set of transversal elements, which, in turn, support the secondary structures of the two decks. The upper and lower decks are stiffened in their own plane by means of bracings, which, during the erection stages, will also bear the horizontal forces; once the structure is completed, these horizontal forces will be carried by a thin concrete slab cast over a collaborating folded sheet.

On both sides, the volume between the intermediate deck and the roof is delimited by a set of columns, emerging from the upper nodes of the truss and supporting the roof beams.

The overhanging balcony at the south front serves both pedestrian and bicycle traffic: this structure is separated from the volume of the main one. Initially, it was supported by I-shaped longitudinal (circumferential) “balcony beams” with variable depth. In the development of the project, the balcony has become a part of a new lateral truss system, as explained in the following.

2.3. The transversal section (the bubble)

In an initial, tentative design, the transversal behavior was governed by a closed frame, in which transversal forces were born by the flexural stiffness of the secondary deck beams, of the diagonals and of the columns supporting the roof, as shown Figure 4.a. Due to the relevant difference between the stiffness of the longitudinal truss beams and that of the balcony beam, the first ones were considered as a couple of rigid supports, while the second as a vertical spring.

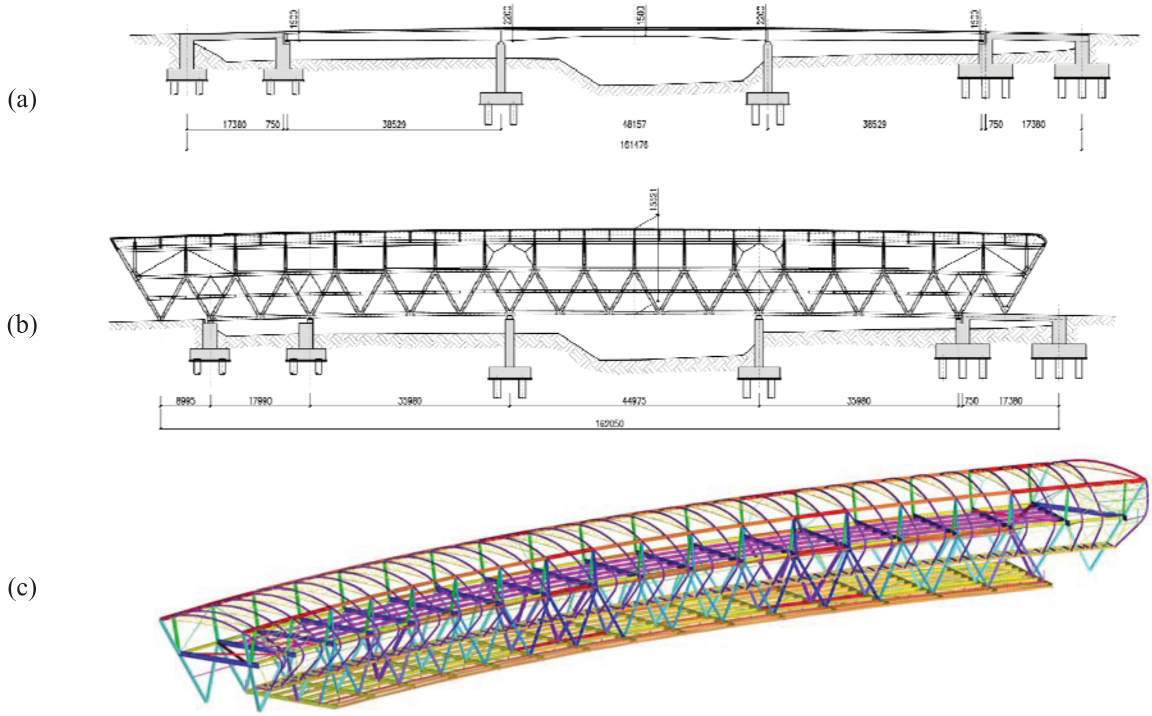

Figure 3: (a) Northern view: the road bridge; (b) southern view: the pedestrian bridge; (c) F.E. model of the pedestrian bridge

The roof was initially supported by beams whose curvature followed the shape of the bubble. The shape of the transversal section was maintained thanks to the stiffness of these massive transversal curved ribs.

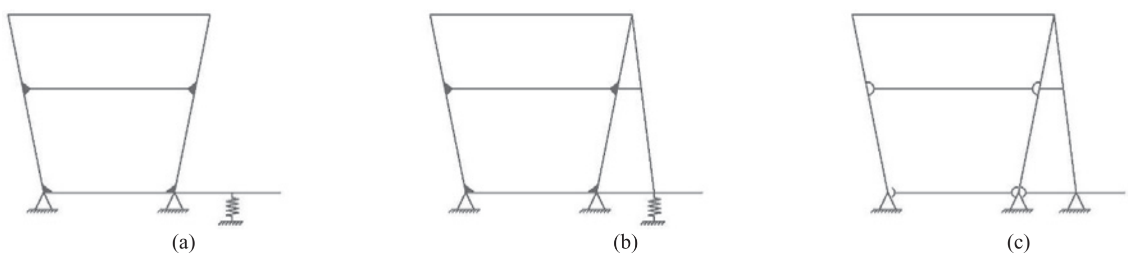

Figure 4: Design evolution of the transversal static scheme. (a) with balcony beam only; (b) with a single strut per segment, thrusting the balcony beam; (c) with V-shaped struts, forming a new lateral truss

At a later stage, it became clear that this solution would require elements which were at the same time too heavy and too deformable in the transversal plane, thus resulting in excessive distortions that made the overall system unsuitable to provide an effective support for bubble surface. The dynamic response under seismic loads stressed all these drawbacks. Since it was required to provide more stiffness than bearing action, the structural steel was inefficiently employed.

As a first alternative, a strut, working as a buttress, was inserted every 9 m, following the pitch of the typical segment of the truss mesh and all along the external pedestrian/bicycle track, as shown in Figure 4.b. In this way, both static and dynamic behaviours were strongly improved and the aforementioned drawbacks eliminated. Such a solution contributed also in increasing the global torsional stiffness of the bridge as a whole, because the insertion of the strut called the longitudinal "balcony beam" to cooperate. The replacement of the original curved beam with a curved truss made the structure stiffer and allowed a remarkable reduction of weight. A further contribution to the stiffness of the covering surface was provided by a light longitudinal truss, connecting the curved beams overhanging the southern parapet, along the entire length of the bridge.

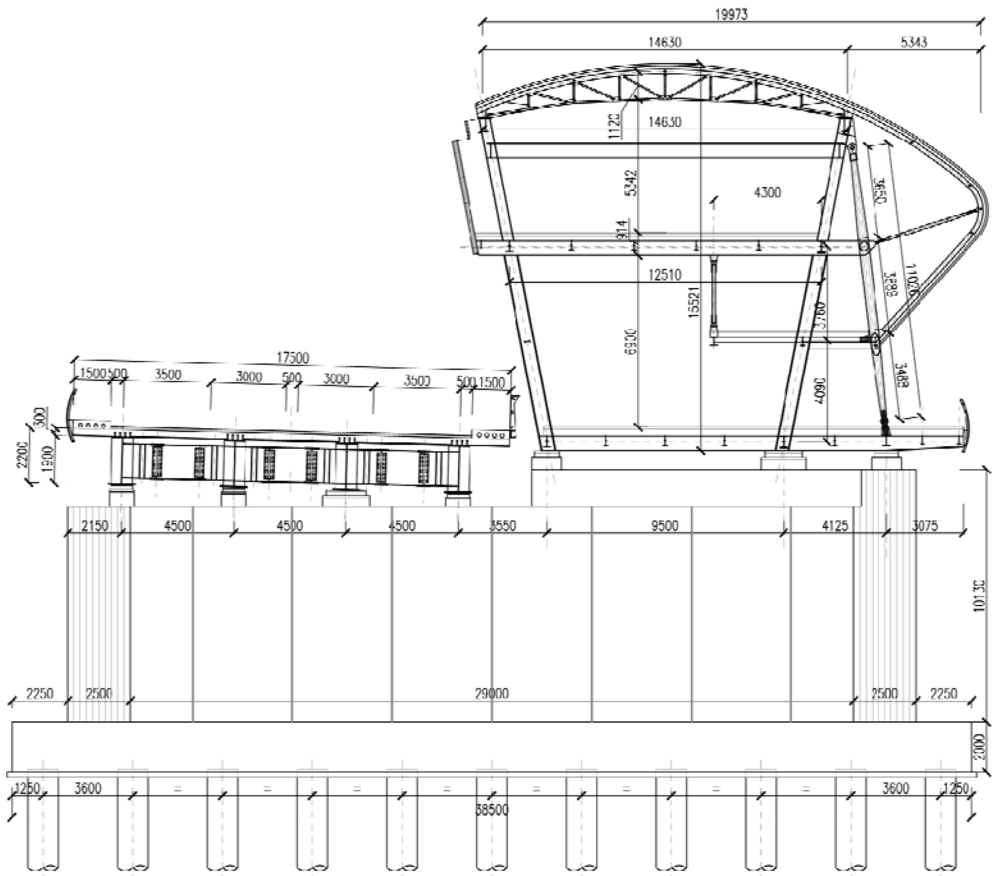

Figure 5: Transversal section of the road and pedestrian bridges astride a pier.

While performing the structural analyses, other possible collaborating mechanisms were detected. In the previous solution, the axial forces in the struts thrust directly on the longitudinal "balcony beam": this beam, even though relatively deep, was much more flexible than the main truss beam. It seemed possible to unify the bearing functions of these structural elements by replacing the single struts with couples of struts arranged into a V shape, having the same pitch and converging to the upper and lower nodes of the south side of the main truss. In this way, the pedestrian bridge turned out to be composed of two parallel

trusses: the main one, which supports the two decks, and a secondary truss at the balcony side, which cooperates with the main one with regard to both longitudinal and transversal behaviours. The original balcony beam was thus no longer called to work in flexure, but became the lower string of the new truss, sided to the main one. As a result, the weight of the balcony beam was strongly reduced and the overall structure became stiffer (see Figures 4.c, 3.c).
The sequence of the V struts seemed a good solution also from an aesthetic point of view, because it recalled the same sequence of struts that can be seen through the glass walls and because it clearly frames the volumes, without obstructing the entrance on the southern front (Figures 1, 2 and 5).

3. The Road Bridge

The depth of the road bridge had to be contained into the narrow band comprised between the road track and the hydraulic clearance. Moreover, the deck profile had to be designed so as not to visually interfere with the main structure of the pedestrian bridge. For these reasons, suspended typologies, like arch or cable stayed bridges, had been discarded and a three spans (38.53 ÷ 48.16 ÷ 38.53 m) continuous slender beam, with a composite steel-concrete section was finally chosen. The transversal section (Figure 5) is made of four I-shaped beams, connected by transversal crossbeams, which support a reinforced concrete slab (250+50) mm thick, connected to the steel girders by means of Nelson joints. The continuity of the deck and the light tapering astride the internal supports allowed to maintain a (1200+300) mm deep section in the middle of the central span and at the two ends, and a (1900+300) mm deep section at the supports over the central piers (Figure 3.a). This choice was also intended to make the erection phases easier. Particular attention was paid to the study of the time dependant effects due to creep and shrinkage, the transversal redistribution of the live loads due to traffic, the corresponding deformation of the deck and the stresses acting on the crossbeams.

4. Abutments. Piers. Foundations.

At the two ends, both the pedestrian and the road bridge are supported by two short approaching bridges; at the middle, they rest on two slender piers placed in the riverbed (Figure 3.a and 3.b). The approaching bridges have a massive r.c. deck, 1.10 m deep and 17.5 m long, which is made continuos at the ends with the vertical walls emerging from the riverbed. The height of these walls, 2.50m thick, varies to follow the riverbed. They rest on footings which are 12.00 m wide, 2.00 m deep at the left bank, and 2.50 m deep at the right bank. Both footings lie on sets of ϕ=1.20 m, 30.00 m long piles (14+14 piles at the left side and 21+30 piles at the right side).

The central piers are 8.65 m high and are arranged radially with respect to the circular road track, at an average distance of 48 m. Their transversal section is 34.00 m long and 1.50 m wide. The ends are slightly tapered. Both piers rise from massive footings 38.50 m long, 7.00 m wide and 2.00 m deep. The footings lie on a set of 11+11 ϕ 1.20 m piles, 29.00 long.

5. Bearing Supports and Seismic Devices

The structures of the bridges are loaded by the vertical loads, due to selfweight and traffic, and by the horizontal loads due to the braking force, to the wind, to the seismic action and to the parasitic forces exerted by the bearing devices. Both bridges lie on four sets of bearing supports: the road bridge sets are made up of four devices, while the pedestrian bridge sets comprise of three. Each set includes one hysteretic dumper, working in the transversal direction, and multidirectional bearings (three for the road bridge and two for the pedestrian one). All the horizontal forces in the longitudinal direction are held by the bearings placed on the approaching frame bridge at the right bank.

The use of antiseismic bearing devices allowed (a) to modify the dynamic response of the overall system, by increasing its vibration period; (b) to dissipate the kinetic energy due to the earthquake, through the elastoplastic flexure of steel elements; (c) to limit the intensity of the forces transmitted by the decks to piers and abutments to the maximum intensity allowed by dumpers. The dumpers were chosen according to the following criteria: (a) the total yielding force had to be greater than 1,5 times the horizontal design forces, with the exception of the earthquake; (b) the ultimate horizontal bearing capacity was assumed as 1,15 times the yielding force. The intensity of this force is the maximun horizontal force acting on the support structures in case of earthquake.

6. Conclusions

This paper presents the criteria followed in designing the new Europa Bridge, currently under construction in Parma, Italy. The bridge is composed of two distinct structures: a road bridge and a covered pedestrian bridge, which enwraps a two level hall, intended to become an exhibition centre. The paper describes the structural concept and the main characteristics and static role of the different parts of the bridge.

7. Design Staff

The design staff of the new structure was composed as follows:

- Owner: Authority for Urban Transformation, Parma. Francesco Fochi and Tiziano Castrogiovanni.
- Contractor: Impresa Pizzarotti & C. and CODELFA S.p.A, Italy. Manager: Aldo Buttini.
- Architectural Design: Vittorio Guasti Architettura S.r.l., with Stefano Granelli, Parma, Italy.
- Structural Design: P.Giorgio Malerba, Paolo Galli, Marco di Domizio, Matteo Patelli, Milan, Italy
- Construction and Site Engineering: Paolo Sorba, Aierre P&L Engineering, Parma, Italy.
- Plant Design: Pool Engineering, Mareno di Piave, Treviso, Italy.
- Environmental Planning: Ambiter S.r.l., Parma Italy.