DESIGN OF PONTE DEI CONGRESSI IN ROME, ITALY

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SUMMARY

The Ponte dei Congressi is a new bridge designed for the city of Rome over the River Tiber. This design is developed by the professional association of engineers and architects who won the international design competition held for this bridge in 2001. 15 years later this project is becoming a reality, with construction due to start in 2016. The design has been adapted and renewed according to the new conditions of the road and traffic design planned in the area. The new design is a steel bowstring arch bridge with 175 m main span, which holds a 24.5 m wide deck, and two side footbridges that are suspended from the deck at a different level, in order to a link the footpaths and bicycle lanes at both river banks. It forms part of a large road connection operation improving South West access to the city of Rome from Fiumicino Airport.

Keywords: *Arch Bridge, Rome, River Tiber, Steel arch, bowstring.*

1. DESCRIPTION OF THE BRIDGE

The design for the new Ponte dei Congressi over River Tiber in South West Rome, is an arch bridge which crosses completely the river bed without intermediate supports.

This design is developed by the team of engineers and architects that won the international design competition held in 2001. 15 years later the project will finally become a reality.

This bridge is the characteristic element of the complete operation, and thus it has a symbolic and iconic value. This reason leads to choose the arch form, strongly related to Roman architecture, as the best option for the new gate to the city, when arriving from Fiumicino Airport.

The plane topography of the river course and the nature of the terrain, with low mechanical properties and big deformability, are not favourable to adopting standard arch typology: the structural efficiency of the arch is conditioned by the capacity of the terrain to develop the horizontal reaction due to the arch thrust. Thus, the chosen typology is a tied arch or “bowstring” arch, in which the horizontal forces of the superior arch are taken by the deck, and the piers receive only vertical forces.

Fig. 1. *General elevation of the Ponte dei Congressi tied arch bridge.*

The bridge has a total length of 259.10 m and a main span of 175 m. It is made out of a double arch in steel with a total height around 40 m (Fig. 1), which suspends a composite deck in steel and concrete of a width of 24.5 m, with hanger cables in vertical planes every 6 m.

At both sides the hanger cables are anchored to the deck, which has the structural function of supporting the traffic live loads, but also of acting as a horizontal tie that equilibrates the horizontal thrust of the arches. With this solution the terrain only supports the vertical reactions, which are transmitted to the bored piles of the foundation.

Over the deck, four traffic lanes are foreseen, all running in the same direction, according to the new traffic configuration that is defined in the project. This configuration invalidates the initial design which included only one arch at the median of the road.

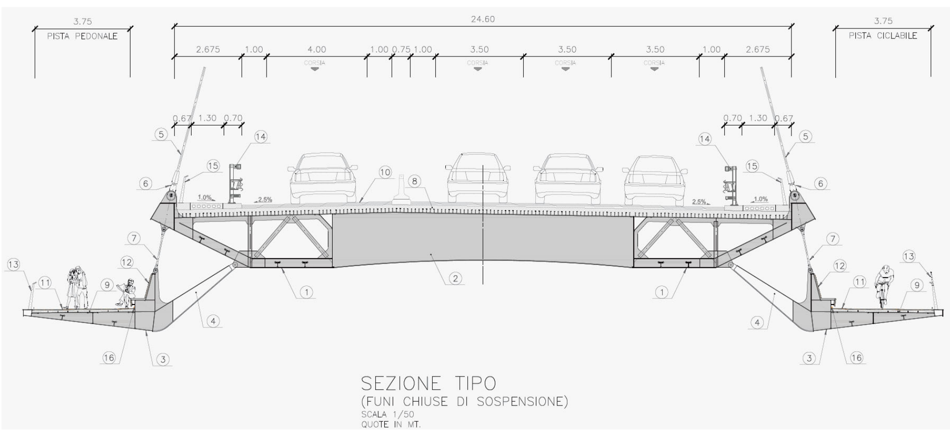

Fig. 2. *Typical cross section of the bridge deck.*

The deck is made out of two side box girders in steel (Fig. 2), with trapezoidal section and high torsional stiffness, with transverse beams also in steel, corresponding with the anchoring sections of the hanger cables every 6 m, and a concrete slab of a maximum depth of 35 cm. Total depth of the deck is up to 2.5 m.

Suspended from the deck, at both sides, there are two footbridges acting as a walkway and bicycle path respectively, with a free width of 3.75 m, which allow the connection between the two walkways foreseen in the project of the river banks, which run at a lower level than the traffic of the vehicles, and allow direct contact with the river.

The road geometry, with the four lanes dividing and opening towards the South bank forces the arches to adopt a spatial configuration that allows to contain this variable geometry.

As shown in the attached figures corresponding to a top plan view (Fig. 3) and an external cross section (Fig. 4), the two steel arches come close at midspan section and diverge towards the connections with the deck. To increase the transverse stiffness of the structure and to avoid instability, four connections are foreseen between the arches, leaving three internal openings.

Concerning the response to seismic actions, the city of Rome is in a low seismicity area, but it is still important to reduce the effects of the earthquake action in the deep foundations, and a seismic isolation of the complete bridge structure is foreseen, with seismic isolation bearings at the main arch bridge supports.

A more detailed description of the different parts of the bridge follows in order to give the most important details of the structure.

1.1. Arches

The arches are the main elements of the new bridge. They allow the bridge to span 175 m over the river without intermediate supports. The total height of the arches related to the deck is around 40 m (Fig. 5), which represent a height to span relation of around 1 to 4.4, which configures a classical arch profile.

There are two separated arches at inclined planes which bend and diverge at both entrances of the bridge. The arches are only separated 2.6 m apart at midspan section, and grow apart to be supported at bearings 49.2 m apart below the deck. This separation does not only gives them transversal stability, but allows the deck to pass through the arches both at the straight North entrance and the South entrance in which the deck widens to open in three different structures.

The arches are connected through four cross elements that stiffen the arches against instability and also receive the deviation forces at the bending of the arches.

The arches have steel trapezoidal sections, with variable height and width. The arches have curved profile and surfaces that bend in the air. The arches height varies from 1.80 m at key section to 3.3 m at the initial section, and its width vary from 2.2 m at the central part of the arches to 3.2 m at the initial section. The arches have a typical steel plate thickness of 40 mm.

There are main diaphragms every 6 m corresponding with the anchorage of the hanger cables, and intermediate diaphragms at 3 m of the hanger cable anchorage sections.

***Fig. 3.** Top plan view of the Ponte dei Congressi with diverging road alignment at South Bank.*

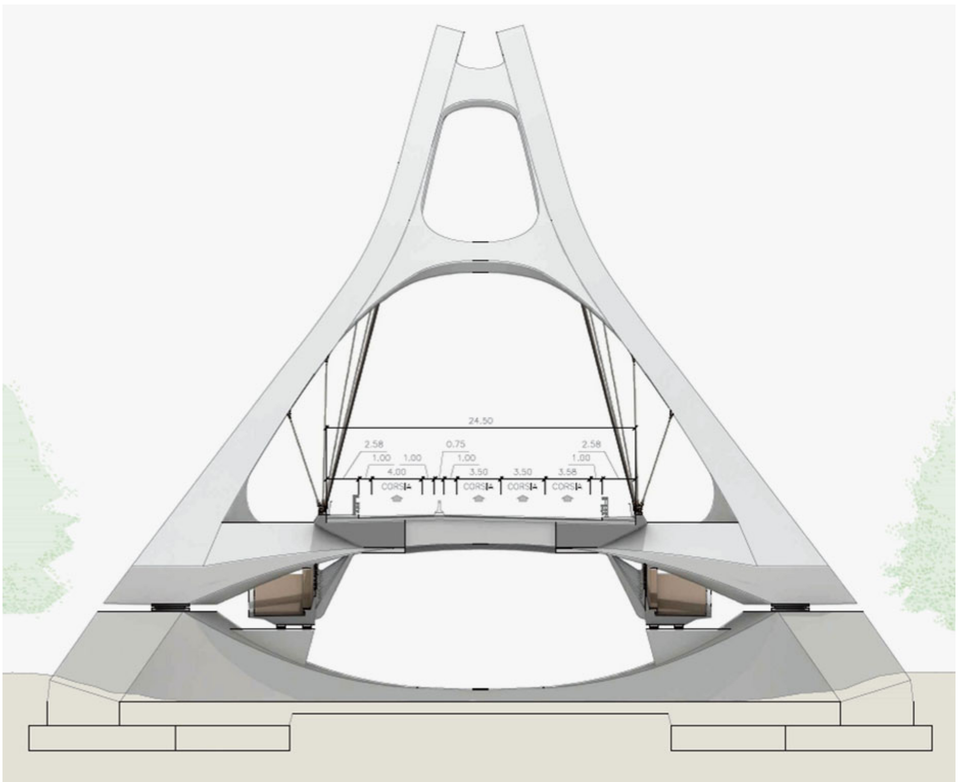

***Fig. 4.** Cross section view from outside the arches.*

A transverse beam connects the arches also at supports section, serving as support of the deck and equilibrating the horizontal transverse forces. The longitudinal horizontal forces of the arches are taken by the deck in a tied arch “bowstring” configuration. A diagonal frame element or strut at each corner at the deck level allows connecting arches and deck, and transmitting these forces. One of the most important structural and aesthetical features of the bridge is the fluidity of this connection, with curved plate elements and soft transition between them.

Fig. 5. *General perspective of the arch bridge.*

1.2. Deck configuration

The bridge is divided in three spans 45.5+175+38.6 m. The deck has variable width, especially in the third span in which the deck divides into three substructures when the main traffic lanes divide in three roads and 5 lanes.

Typical width in the main span is 24.5 m. The road is 19.25 m wide, with four lanes (3x3.5 m and 1x4.0), median of 0.75 m, and 4 shoulders of 1 m. The outer shoulder increases up to 2.25 m at the South exit due to the curve alignment. At each side there is a space of 0.70 m for the traffic barrier, 1.30 m emergency walkway and 0.67 m to include the railing and hangers anchorages. The emergency walkways respect always a minimum width of at least 0.90 m even at the South East corner arch support, in which the critical geometry section is located. Vertical clearance over the road of at least 5.5 m is always respected with at least 2 m over the walkways. At both sides there is a border element that has both an architectural function and also a structural function including the anchorages for the hanger cables.

The deck is formed by two composite side box girders and a central slab supported on transverse steel beams. Typical box girders are 7.25 m wide, have a horizontal bottom face of 3.3 m, and an inclined lateral face. The depth of the steel box girders varies and has a typical value of 2.16 m and 2.00 m in the left and right box girders.

The transverse steel beams are formed by double T steel beams of 750 mm width and variable height, which are placed every 6 m. Main diaphragms in the box girders are placed every 6 m and intermediate diaphragms at 3 m of main diaphragms.

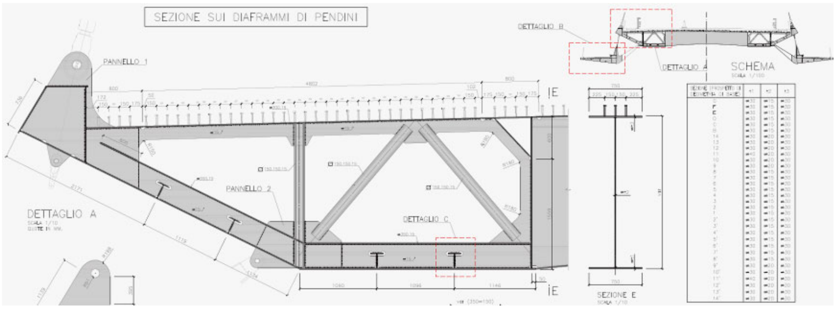

Fig. 6. *Detailed configuration of the deck box girders.*

The concrete slab has an average value of 30 cm and it is poured on precast slabs.

Total depth of the deck is 2.4 m average, which means a depth to span ratio of 1 to 19 for the access span of 45.5 m, and 1 to 73 for the main span of 175 m.

The deck has an average longitudinal slope of 0.5%, that means also the hanger cable planes are inclined a 0.5% related to the vertical plane.

Fig. 7. *Render view of the bridge deck.*

1.3. Side footbridges

Two side footbridges allow connecting the new paths along the river at the riverbanks. One of the footbridges is a walkway and other a bicycle path. The footbridges are at a lower level than the road deck following a curved profile in elevation and increasing its height towards midspan section, in order to leave a bigger free height clearance above the river. The height difference with the road level is around 7.4 m at support sections and 3.8 m at midspan section. River clearance at midspan is over 12 m.

These side footbridges are steel structures that suspend laterally from the deck at each side every 6 m. The suspension is made by means of stainless steel tension rods type S460 M56 of 50 mm diameter. Also a steel strut stabilizes the footbridges against transverse bending and rotation.

The footbridges deck is about 5.25 m wide, including a longitudinal bench and a railing. The free width of the pathway is 3.75 m. The steel structure has a total depth of 2.3 m including the bench back element. The pavement is made of greenwood type composite wood elements, and includes a 7 cm concrete slab to stiffen the steel deck. At each side of the 175 m main span, an access span allows the footbridges to connect with the river bank pathway.

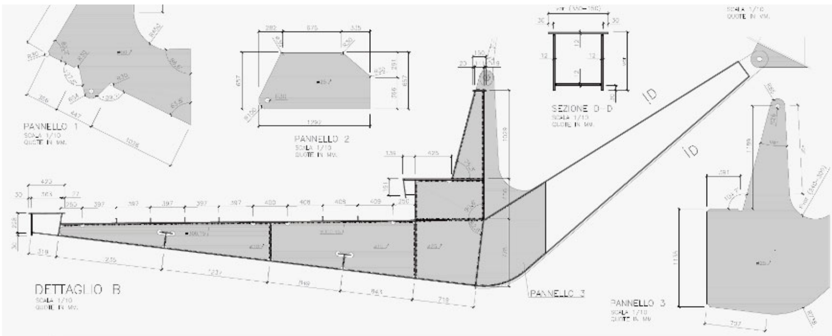

Fig. 8. *Detailed configuration of the side footbridges.*

Fig. 9. *Render view of a side footbridge.*

1.4. Hanger cables

The deck suspends from the arches at the 175 m main span by means of hanger cables placed at planes every 6 m. There are 25 planes of 2 hanger cables, one at each side of the deck. The hangers are locked coil strand cables of 70 mm diameter, of 4890 kN breaking load. The cables have spelter socket hinged ends at both sides, and an adjustable threaded socket at the active end to allow tensioning. Tensioning will be done during construction process with the aid of temporary external equipment which anchorages at the cable and the steel structure. The length of hangers in between hinges varies from 8 m to 37.4 m.

The locked cable has a special cross section with three layers of Z shaped steel wires to avoid water entering the cable and protect from corrosion. Additionally the cables will be galfan coated as additional protection against corrosion. At least one hanger cable will be fully tested until breaking before construction.

1.5. Piers and foundations

The bridge deck is supported on 4 pier alignments, P1 to P4. P2 and P3 are the main piers and represent the arch supports. P1 and P4 are the transition piers to the access viaducts. P4 is formed by piers P4a, P4b, and P4c as the deck divides in three at this point. The transition piers P1, P4a, P4b and P4c do not form part of the project section of the Ponte dei Congressi.

The piers P2 and P3 are sculptural elements that do serve as support to the arches and the deck, and also give architectural continuity to the arches towards the ground. Each of the piers includes the bearing to support the arch and deck, and the bearings that give intermediate support to the side footbridges.

Each of the four main foundations is formed by 16 bored piles of 1.50 m diameter, and 60 m length.

1.6. Bearings and expansion joints

From a seismic point of view the bridge acts as an isolated structure. That means the bearings completely isolate the bridge from foundations in order to reduce the forces transmitted to them. The main 4 bearings are friction isolation pendula which have additional benefits, as increasing the vibration period and the structure damping. These curved sliding bearings have also recentering capabilities that allow having all other bearings in the bridge as standard sliding bearings. The resulting displacements are around +/- 200 mm both in longitudinal direction. More accurate study of the seismic bearings can adjust these displacements if necessary.

The main bearings in piers P2 and P3, below each of the 4 arch supports, are friction isolation pendula with a maximum design load capacity of 50.000 kN, average load of 32.000 kN, maximum displacement of 300 mm in any direction, friction coefficient of 3.63% and equivalent curvature radius of 3700 mm.

The bearings in transition piers are free sliding neoprene POT bearings. They will also allow movements of +/- 300 mm in any direction. The load capacity of the bearings is 8000, 9000, 8000 and 8000 kN, for P1 (2 bearings), P4a (2 bearings), P4b (1 bearing) and P4c (1 bearing) respectively.

The bearings that support the footbridge at the main piers support axis (PP2 and PP3) and the end abutments PP1 and PP4 are free sliding elastomeric bearings allowing also movements of +/- 300 mm in any direction.

The expansion joints are modular type joints which allow movements both in longitudinal and transverse direction up to +/- 240 mm.

2. CONSTRUCTION PROCEDURE

The Ponte dei Congressi erection procedure has been developed with the aim of respecting as much as possible the environmental conditions of the River Tiber banks and river. That is the reason why a floating and lifting operation for the deck's central span section is chosen, with later erection of the arch on temporary towers (Fig.10 and 11) to minimize the affection to river and not disturb the flora and fauna of the area.

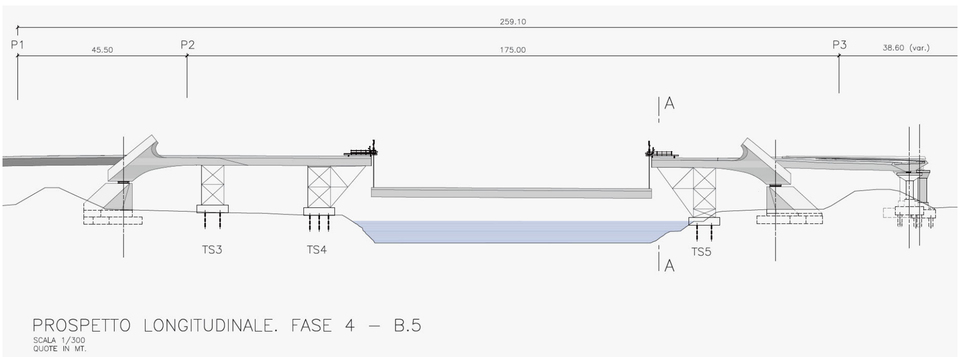

Fig. 10. *Flotation and lifting of the deck over the river, using temporary supports.*

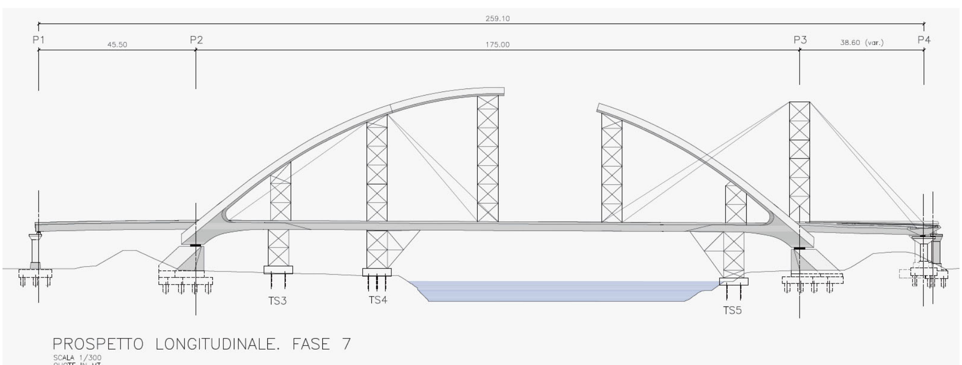

Fig. 11. *Erection of the arch using temporary towers and cable staying.*

3. STRUCTURAL ANALYSIS

A complete structural analysis of the bridge (Fig. 12) is carried out during the design including the global model, seismic analysis, global buckling verification and modes of vibration. The tied arch structure is validated showing a good structural behaviour.

Fig. 12. *Global FEM model of the bridge.*

4. CONCLUSIONS

The new design for the Ponte dei Congressi satisfies the structural, architectural and aesthetical objectives of the project and the choice of the tied arch typology results in a sophisticated structure which responds at the same time to classical and innovative standards which the site conditions and the importance of the structure require (Fig.13).

Fig. 13. *Render view of the aesthetical result of the Ponte dei Congressi.*