TWO FOOTBRIDGES

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Abstract

The first footbridge built over the river Reno is a pedestrian and bicycle path and has an approximately 100 m free span.
The structural solution basically consists of:

- One main spatial carrying cable system;
- One system of stabilizing ropes with opposing curvature;
- Two anchor frames with gravity foundations.

The main supporting system is composed of two carrying cables with a 98 m free span and 15 m sag. Both carrying cables are constructed with spiral high resistance individual wires plus Z-shaped external wires (locked coil system) cables, protected from corrosion through galvanizing and having a 60 mm nominal diameter.
In order to achieve a stable system also in terms of the lateral forces due to the wind, such carrying cables were arranged according to a space pattern envisaging diagonal lines, at first implementing a natural equilibrium setting (state 0) depending on the load distribution and the linear constraint conditions.
The stabilizing system is composed of cables with opposing curvature arranged along the external perimeter of the deck structure. These cables allow achieving a double-effect vertical system, thus generating a tension-structure response system, unlike the traditional stabilization by gravity of merely hanging decks.
The second footbridge in Casalecchio di Reno is aimed at connecting the two banks of the Reno river and has a 100m maximum free span.
The structural architecture conceptual design is inspired by the shape of a swan, in particular its lightness and elegance, and resorts to materials such as steel, capable of ensuring a favorable weight-resistance ratio, and a series of original structural solutions aimed at minimizing the weight of the structure and, consequently, the total cost of work.
The deck structure includes a reinforced concrete slab on 9 cm tall corrugated steel metal sheet and is supported by transversal elements arranged at a constant 2,5 m centre line which convey the load of the deck structure on a box girder with polygonal section, the extremities of which are hinged and supported by a series of stay-spiral cables in 4 sections.
The stayed incline column, composed of two box sections, reaches a 25,05 m maximum height with 44 degree angle towards the centre line of the bridge. Four stay-cables depart from the top and support the deck structure by means of 4 adequately stiff transversal beams anchored to the deck structure by means of triangular shaped plate elements capable of preventing any parasitic flexures affecting the bridge deck.
The cable axial forces are oriented towards the anchoring structures after being deviated in a zenith point corresponding to the connection point among the deck beam, the antenna and the two box girders following, in plan view, the development of the box girders.

Keywords: Conceptual design, suspension, cable-stayed, detail design.

1. Footbridge over the Reno – Bridge of Peace

1.1 Description of the structure

The footbridge built over the Reno river is a pedestrian and bicycle path and has an approximately 100 m free span.
From the town planning viewpoint, it contributes to the definition of a pedestrian and bicycle connection route playing a major functional and symbolic role.
Also in terms of the recovery of the identity of the town, the selected location allows those who cross the footbridge to directly enjoy important venues of the Casalecchio town structure, in particular the S. Martino church, the ancient brick wall and the ancient Scaletta, S. Luca and Verrocchio docks of the Reno canal, and the Eremo di Tizzano church.

Figure 1: Full daylight and night views of the footbridge "Bridge of peace"

The architectural and structural project took into in particular account the functional, environmental and economic limits set by the Clients.
Based on those specifications, after a comparative typological analysis, a pre-tensioned suspension bridge was selected, which allows to eliminate the deck structures with longitudinal flexural rigidity (which minimizes the environmental impact) and supports the wooden floor simply by means of transversal bent beam elements (gondole), which in their turn hang from the fully locked carrying cables by means of spiral cables stays.
The structural solution basically consists of:
- One main spatial carrying cable system ;
- One system of stabilizing ropes with opposing curvature;
- Two anchor frames with gravity foundations.

1.2 The main supporting system

The main supporting system is composed of two carrying cables with a 98 m free span and 15 m sag. Both carrying cables are constructed with spiral high resistance individual wires plus Z-shaped external wires (locked coil system) cables, protected from corrosion through galvanizing and having a $\phi = 60$mm nominal diameter.
In order to achieve a stable system also in terms of the lateral forces due to the wind, such carrying cables were arranged according to a space pattern envisaging diagonal lines, at first implementing a natural equilibrium setting (State 0) depending on the load distribution and the linear constraint conditions.
This configuration mainly originates from the shape of the deck structure, the width of which ranges, according to a double parabola, between 2.50 m at the springing and 6 m in the centre line, which, through the very deck structure, ensures a wind bracing function outside the vertical plane.
The sag rods connecting the deck structure and the carrying cables are composed of $\phi = 16$mm – 19mm galvanized fully locked spiral ropes; they hold the deck structure every 2.50 m by connecting to enclosed Fe 430 D steel transversal beams with variable span and convey the stress to the carrying cables through special friction grips.
The deck structure is 98.00 m long between the anchor frames and is in ad-hoc treated 0.07 m thick, 0.20 m wide and 5.00 m long larch wood tables.
The fillets are laid longitudinally with reference to the crossing direction of the pathway, placed one next to each other with a few millimeter span to allow the flow of water and the usual expansion of wood itself (Figure 2).

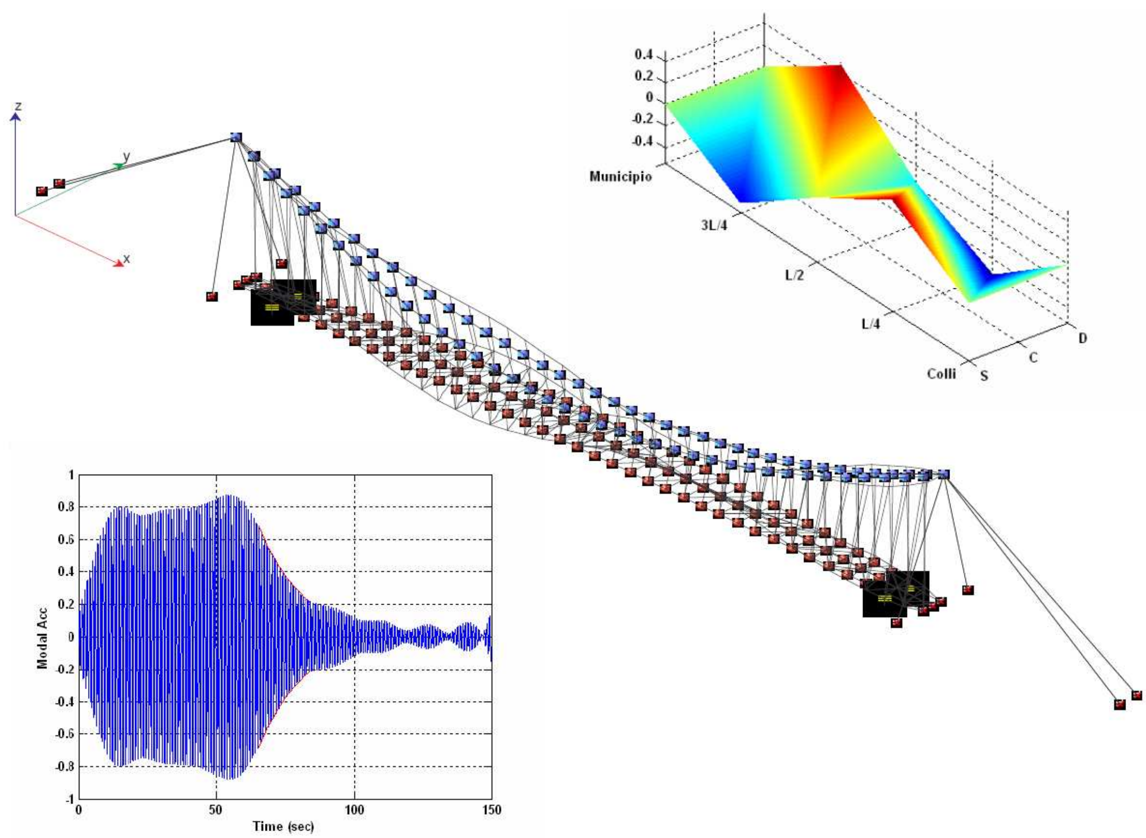


Figure 2: Numerical dynamic model of the suspended footbridge

1.3 The stabilizing system

The stabilizing system is composed of cables with opposing curvature arranged along the external perimeter of the deck structure. The cables, with a 40 mm nominal diameter, have an initial pre-stressing force of 500 KN.

The stabilizing cables allow achieving a double-effect vertical system, thus generating a tension- structure response system, unlike the traditional stabilization by gravity of merely hanging decks. Due to the shape design of the deck, the stabilizing cables have a spatial double curvature in the vertical and horizontal planes so as to achieve an effective response against the gravitational loads and the lift and drag actions due to the wind.

The stabilizing cables are anchored to a foundation in reinforced concrete.

1.4 Anchoring supports

The tensioned structure system formed by carrying and stabilizing cables generates tension stress at the sides, with horizontal and vertical components, which are balanced and conveyed to the ground through an anchoring system. The present project implemented an anchoring frame system composed of two “A”-shaped steel columns and a guying composed of four stay ropes with 40 mm diameter, fan arranged on the longitudinal vertical plane (Figure 3).

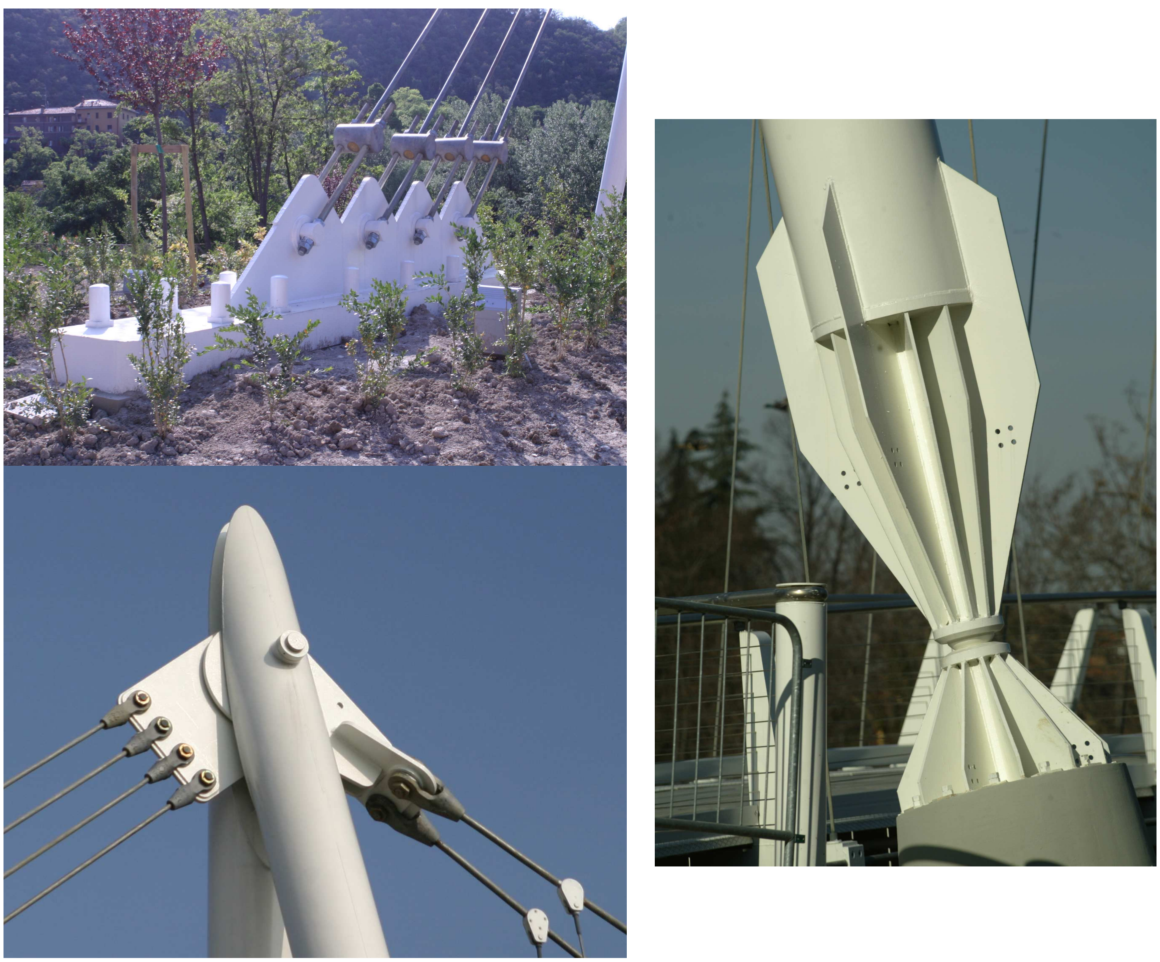


Figure 3: The anchoring support

The carrying cables meet in the anchoring point at the top of the support columns, where a particular hinge pin structural device was developed which allows to connect the carrying cables, the stay ropes and the A-shaped columns, thus automatically leading the various components to a state of equilibrium in operating conditions and facilitating assembly operations as well.
The A-columns are approximately 22.00 m tall above the ground and are built with S 355 steel circular hollow structural section, 711.2 mm diameter and 12 mm width, hinged at the base.

1.5 The foundations

The column forces are transmitted to the reinforced concrete foundation system.
Based on the geotechnical properties of the site, direct-type foundation solutions could be implemented.
The stay-cable forces, generated by the structural system response, are counterbalanced by gravity foundations, typically used in cable-stayed and suspended bridges. The gravity cable stay anchorage foundations are located approx. 22-23 meters away from the columns described above, where the equilibrium of forces is achieved vertically through the weight of the foundation itself and horizontally through the combined contribution of friction and a certain soil passive pressure share.
The foundation of the columns may be compared to a retaining wall loaded vertically by the columns and horizontally by the stabilizing cables.

Footbridge over the Reno river – “Canonica”

2.1. Description of the structure

Also the new footbridge in Casalecchio di Reno is aimed at connecting the two banks of the Reno river and has a 100m maximum free span.

Figure 4: Full daylight view of the footbridge “Canonica”

The structural architecture conceptual design is inspired by the shape of a swan, in particular its lightness and elegance, and resorts to materials such as steel, capable of ensuring a favorable weight-resistance ratio, and a series of original structural solutions aimed at minimizing the weight of the structure and, consequently, the total cost of the work.

2.2 The bridge deck

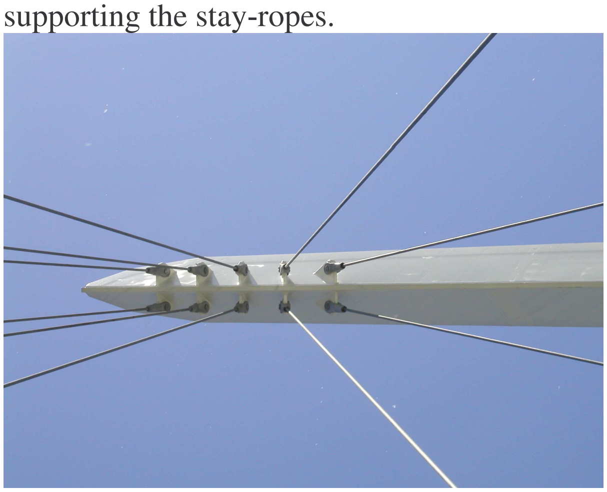
The deck structure includes a reinforced concrete slab on 9 cm tall corrugated steel metal sheet and is supported by transversal elements arranged at a constant 2.5 m centre line which convey the load of the deck structure on a box girder with polygonal section, the extremities of which are hinged and supported by a series of stay-ropes in 4 sections.

Figure 5: Rendering model of the footbridge

The solution implemented, i.e. the use of a reinforced concrete slab instead of the traditional orthotropic plate is aimed at ensuring stability to pedestrian dynamic actions, as well as greater stiffness to the deck structure on its plane; this advantage is achieved by implementing a composite steel-concrete section trough stud connection between the concrete layer and the steel box supporting structure.
The section of the bridge deck varies:, the cross section starts at the left bank support from a minimum value of 2.5 m and then increases while approaching the right bank to reach a 6 m width at the stay-rope holding antenna (located approximately 80 m away from the left bank), where the "pathway" is divided into two symmetric 3 m wide parts, in their turn supported by cantilever beams projecting from a box girder located in a lateral position.

2.3 The main supporting system

Going from the right to the left bank, also the two beams supporting the deck structure progressively increase their cross section until the point where they are hinged in the central abutment, then they continued in an inclined position to form the antenna supporting the stay-ropes.



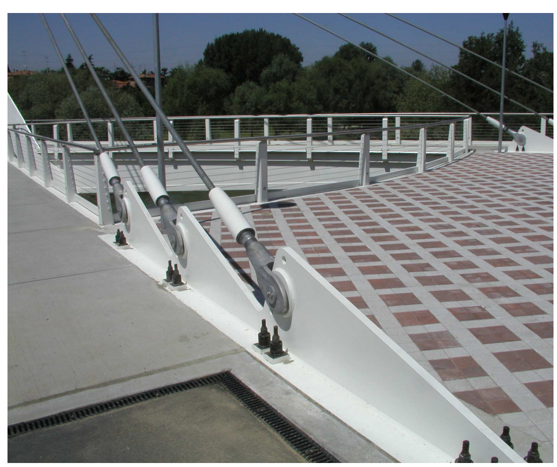


Figure 6: The anchoring support

The stayed inclined column, composed of two box sections, reaches a 25.05 m maximum height with 44 degree angle towards the centre line of the bridge. Four stay-cables depart from the top and support the deck structure by means of 4 adequately stiff transversal beams anchored to the deck structure by means of triangular shaped plate elements capable of preventing any parasitic flexures affecting the bridge deck.
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