HISTORICAL ANALYSIS AND RECONSTRUCTION OF THE SUSPENSION BRIDGE LEOPOLDO II IN POGGIO A CAIANO, ITALY

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Summary
The bridge described in this paper was built at the beginning of the 19th century, thanks to the progress and to the industrial revolution.
In Poggio a Caiano, in Tuscany, a very old suspension bridge: "Leopoldo II" from the name of the Grand Duke; it is the very first wire suspension bridge in Italy not only for pedestrian and one of the first in the world. The bridge represented the advanced technology, the will to introduce scientific innovations in the art of construction. The Grand Duke Leopoldo II wanted the construction of the bridge in order to be not inferior to the other Sovereign in Europe.
The paper starts with a documentation of the design of the old bridge based on historic documents, presents a verification with numeric models of the old structure, and proposes different design strategies for the reconstruction of the bridge.
It is presents the story of the bridge and of the people who wanted it. Through the knowledge derived by a deep research in historical archives, we tried to understand the reasons and the will that regarded it. The experience and the knowledge that were available at that time are analyzed.
A proposal of reconstruction is made paying attention to the philosophy that was in the previous construction.

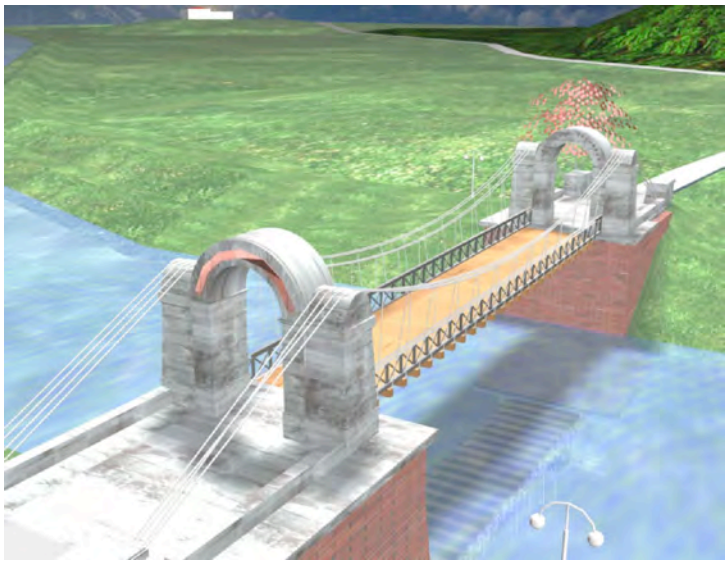
Fig. 1 - 1938 Belli Archive

1. Introduction

At the beginning of the 19th century, thanks to the progress and to the industrial revolution, steel started to be used in civil construction. The advantages of the steel, even from an aesthetic point of view can be seen in suspension bridges. In this kind of structures it is possible to obtain lightness and elegance that were before impossible.
The first suspension bridges were designed in England and in France. As the Grand Duke of Tuscany Leopoldo II knew that, willing to be ahead with the progress, he sent Alessandro Manetti, his best engineer, in France. For this reason, the experiences about French suspension bridges were revealed through the Manetti's direct knowledge, recorded in an ancient day diary (see references). From the personal diary of Manetti we can read: "I made them built a suspension bridge with hemps of iron wire on the Ombrone in the park of Poggio a Cajano [...], it was the first bridge of that kind that we made, suitable for the step of the coaches, and those which it was destined belonged to the Monarchs and the Court".
When Manetti was back he received the assignment to design a cable wire suspension bridge in Poggio a Caiano, (nearby Florence) next to the Royal Palace, to provide a new way out for the Grand Duke to his lands, on the other side of the river Ombrone.
In fig. 1 it is possible to see the bridge, which was the first wire suspension bridge in Italy. The "Leopoldo II" Bridge was constructed in 1833 and was used until the World War II when, unfortunately, the German Army destroyed it. Now only the powerful masonry arcs remind us of his presence and, even though after the World War II they were forgotten, they now capture again our attention although of its small dimension. The bridge has always provoked great admiration and astonishment in the people who crossed it.

The bridge, had three wire cables for each part and a wooden deck, and is remembered as a work of art, as results also from photographic documentation of years around 1935.
Now it is possible to see on both sides of the river the monumental masonry piers. In lately years interest is growing for a restoration of the bridge.

2. Reconstruction of the bridge Leopoldo II



Reconstruction, more than a renovation, puts forward a number of questions to be solved. Does the structure have to be rebuilt exactly the same way as it was? Or is it only the philosophy that was behind the structure that has to be maintained? Very often the loads for which the structures were designed were generally much lighter than the ones that the bridges have to carry today. These condition obligate to change the stiffness of the original structure. Changing the original structure can be made maintaining the philosophy of it. Using different materials can be one solution.
A courageous way of thinking can be the separation of tasks. It is possible to create a main structure with modern and technologic materials and to maintain secondary elements as they were before.

Fig. 2 - Proposal of reconstruction

	Reconstruction	Original
Main span length [m]	34.89	34.89
Width [m]	4.75	4.75
Sag [m]	2.90	2.90
Sag-to-span ratio	1/12	1/12
Cable area [m²]	0.01326	0.02851
Cable modulus Ec [N/m²]	1.62985E+11	1.2962E+11
Truss modulus Et [N/m²]	2.10000E+11	1.0000E+10
Moment of Inertia [m⁴]	0.00680096	0.00024
Dead load [KN/m]	11.26	21.86
Live load [KN/m]	18.92	11.28*
Dead load tension H [KN]	591.019	1147.40
Max increase in cable tension h [KN]	1604.49	1934.22
Deflection v [m]	0.034	0.1536

Tab. 1 - Bridge Properties.

For the Leopoldo II Bridge an exact reconstruction as it was before it is impossible. The loads that the bridge should carry today are much higher than the ones used for the earlier construction, even if a pedestrian solution is chosen. One valid solution can be to change the material of the parapet, originally made in wood, with steel. A steel parapet can have the function of a frame truss with high stiffness.
The use of high technologic strength steel can renovate even the cable system. In the reconstruction proposal a less number of cables are used due to their much higher stiffness, 8 cables, 4 for each part on two different levels can be a solution close to the original design of the bridge. This is a solution that can join the past with the present, shapes who look to the past but with modern substance. The original parapet was made by oak; in the project of reconstruction it is rebuilt with rectangular hollow sections with exactly the same dimensions of the original one. The exact dimensions were founded in historical papers: during renovations of the bridge where presented a detailed report of the work with the dimensions of the renovated elements. The wanted rigidity of the parapet is given by modification of the web thickness. On the table 1 it is represented a comparison between data of the old structure and the project of reconstruction. Due to the lack in bending stiffeness of the original bridge the maximum deflection was really high.

3. Conclusions

When the old structure is not anymore resent, a valid reconstruction should always been supported by an historical analysis.. Keeping always in mind the history of the bridge, the original design's decisions and the philosophy that were around the structure it is always possible to find a right solution. A solution that will respect the original structure, and in the meantime can be modern and highly technological, can always be found.