Conference paper

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Pier Luigi Nervi, bridge designer.

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Summary

“A bridge is for an engineer what a dome is for an architect”.
The construction of a bridge is a central event in a professional life of an engineer. The symbolic value of such a structure, at the same time functional and iconic, is one reason. Moreover, bridge represent the perfect construction to test technological innovations, this can be seen by the fact that many pioneering engineers linked their names to ground-breaking bridges: Maillart, Hennebique and in recent times, Calatrava.
Pier Luigi Nervi, one of the most acknowledged engineer of the twentieth century, famously built many domes but only one bridge, in Verona in 1965, he was 74. However, his interest for bridges was a constant in his professional life. Furthermore, other Nervi’s structures, like the elevated motorway in Rome, La *Via Olimpica* (1960) or even the suspended roof of the Burgo paper mill (1961) can be considered structurally similar to bridges. This paper presents some of Nervi projects of bridges, from the early designs to the what is generally considered his last effort, the Messina bridge. Particularly interesting are the discovery of two projects for such structures recently discovered in the *Archivio Nervi* in Rome. Two images of these projects are presented in this paper for the first time. They are just another evidence of the continuous investigation on suspended structures of the Italian engineer.

Keywords
Pier Luigi Nervi, bridges, suspended structures, steel, reinforced concrete, Messina Bridge.

1. Early projects and concepts

Pier Luigi Nervi designed his first bridge in 1936 for a competition, the project was not successful; this bridge, over the river Biedano, was eventually constructed by Giulio Krall, an expert in bridge construction and a very significant engineer too, in 1939. In 1945, he bid for another project for a bridge over the river Arno, and in 1955 he designed a bridge on the river Tenza, in southern Italy. All the mentioned bridges were designed in reinforced concrete, Nervi’s favourite material.
His passion for such a structure is testified by the article he wrote in 1959, for Casabella [1] called *Cinque Ponti*: Five Bridges: the Salgina bridge (Maillart), the Rodenkirchen bridge over the Rhein, the Golden Gate bridge, the Bridge on the Elba river in Germany and the project for a bridge of the architect P. Soleri). After having briefly described them, he took the opportunity to explain his point of view on the possible two opposite approaches in designing structures:
a) *‘designers, following the statical, constructive and economical needs, and within the margins of freedom in defining structural and formal details, which they always and anyway concede, try to express their own aesthetic sensibility*.’
Or, alternatively,
b) *‘designers start from a purely formal conception, very close to what sculptors could have, and then begin to improve it, with the sub-conscious thought that the ’calculator’ will manage to make it stand and the constructor will be able to build it.’*
In other words, the two approaches are summarised by Nervi in designing:
a) from inside to outside
b) from outside to inside
The former, in Nervi’s opinion, being the correct one.

The precise reference to bridges to define the correct approach to design structure, shows how paradigmatic were these structure to him.

2. Almost bridges

The 1960 Olympic Games held in Rome gave to Nervi a chance to push further his activities both as a designer and as constructor. Indeed Nervi designed several structures for this event; two covered arena and a stadium (the latter with his son, Antonio). In this occasion, Nervi designed also an infrastructure, an elevated motorway which connected the Olympic village to the centre of Rome. The track of the elevated motorway, popularly named *Via Olimpica,* is based on a particular curve, the clothoid, of the family of spirals. The main property of this curve is that the length of its radius decreases according to the overall length of the function. It is a logical shape with a varying radius, in use for the transition of a straight to a circle curve: a vehicle following the curve at constant speed will have a constant change of rotational acceleration, reducing lateral stress on the rail tracks. Moreover, due to its particular shape, it is easier for a driver to approach the curve in a smoother way compared to a constant radius curvature. The construction system was based on a perfect synergy between prefabricated elements (the shelves) and in-situ cast pillars. Only three forms for the erection of the 120 pillars, which have a variation in height between 3.5 and 8 m due to the inclination of the ground of 2%, were employed, re-using them forty times each. The tallest elements were cast first, then the forms were resized by cutting them from below for the shorter one, and so on (Fig. 1). The cruciform base of the vertical supports is transformed into a rectangle at their top in order to offer a perfect area to the above shelves, by a *metamorphosis* already seen in other works of Nervi, as an a example, in the UNESCO pilotis (Fig. 2).

Fig. 1 La Via Olimpica, Rome 1960

Fig. 2 UNESCO, detail, Paris 1953

Shortly afterward, in 1961, Nervi designed a mega-structure, The Burgo paper mill, in Mantua (Fig. 3). In doing this, Nervi was perfectly aligned to other designers dealing with the same architectural theme (Archigram, Hollein, Piano and Rogers).

Fig. 3 The Burgo paper mill in construction, 1961

The Burgo paper mill is gigantic box which contained a huge machine to produce paper.
Nervi approached the project of Burgo factory conceiving the structure as three separate elements, a basement, four curtain walls and a suspended roof. The design and the structure of such a roof resembles very close the project of a suspended bridge. In this case, Nervi was assisted by Gino Covre, responsible for the design of the steel cables.

After the international success of his works in Rome, Nervi began to work abroad. In the beginning of the '60, Nervi concentrated his energy in several projects in the USA. In 1962, he collaborated with Kaiser steel, a Californian steel company. Kaiser steel asked Nervi to design an elevated urban road and a bridge in San Francisco. For such a project, Nervi proposed two options, one in reinforced concrete and one in steel. The project was unsuccessful for financial reasons.
In 1963, Nervi was approached by the Department of the Public works of the state of California in order to design a bridge over San Mateo creek, in steel. The bridge was supposed to span for 550 metres long and to be 76 meters off the ground at the deepest level.
In these designs, unpublished, and very little known, Nervi re-interpreted the solution he proposed only few years before. *La Via Olimpica (1960)* constitutes the reference for the design of the pillars for S. Mateo bridge. The supports of the canopy of UNESCO headquarters *(1953)* are re-proposed for the skyway in S. Francisco. Interestingly, despite to the formal analogies with their predecessors, both the American projects were conceived in steel, a material Nervi was starting to use more and more. (Burgo paper mill, Mantua; Palazzo del Lavoro, Turin).

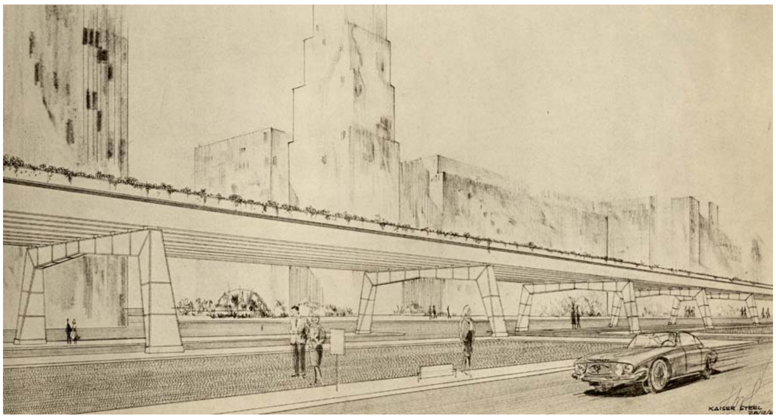

Fig. 4 Project for a skyway San Francisco, 1962

Fig. 5 San Mateo creek Bridge, 1963

3. Building the bridge

Finally, when in 1965 Nervi was commissioned to design and build the Ponte Risorgimento, in the northern Italian city of Verona, he was 74 years old, at the apex of his career. Nervi at that time was able to select his clients, leaving minor jobs to the Studio Nervi, a young practice lead by his first son and active collaborator, Antonio, an architect. In the Studio Nervi, Pier Luigi was an official member, however his role was to mainly supervise and control the projects conceived by the group of young designers. Interestingly, Studio Nervi was originally founded by Antonio Nervi and Sergio Musmeci, a very talented structural engineer.
Verona has virtually a bridge for every historical age, starting from the Ponte Pietra, a Roman structure, the beautiful medieval Ponte Scaligero and finishing with the bridges constructed during the Asburgic domination to modernise the city. The strategic and military character of Verona is testified by the tragic destruction of each bridge on the 25 April 1945 by the retreating German army. After the war, they were all reconstructed. In such an Architectural challenging environment, Nervi, an engineer, designed a magnificent structure, one of the most sensual of his entire career, a clear sign of his maturity as a pure designer, showing in some respects a certain mannerism, in its highest aspect. An advanced piece in Nervi'style but still coherent with his earlier compositions. His rational inspiration is transformed here into a sensual form, Nervi reached in this work the skills of the sculptor in mastering the pure matter. However, in his creation a careful attention is dedicated to the Urban context, to the history of the city. In approaching this design Nervi carefully studied all the bridges present in Verona. The complete collection of photographs are still kept in the Nervi's archive. However, despite the presence of the past was something to take into account in designing a new structure in a historical context, Nervi also thought that:
Verona is a challenging city. The structure [the bridge] is to be build in the proximity of the bridge of the Castello Scaligero: they face each other. We can not re-propose the old which we are not able to do any longer anyway. We must do something new. And do something new is challenging. [2]

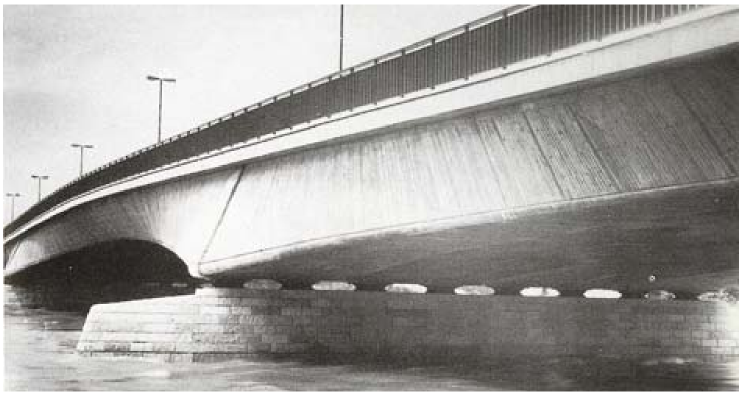

Fig. 6 Risorgimento bridge in Verona, 1965

The structure links the two banks of the river Adige, which are 130 meters apart. The easiest and less expensive solution was to build a girder bridge over two central pylons. This scheme was also in line with the many wonderful examples of the past present in Verona. As usual, Nervi's first layout was influenced by a rational approach, with particular regard to statics laws. In order to understand Nervi's design process for this particular structure, it is sufficient to analyse a typical diagram of a horizontal beam on four rollers, which represents this bridge on four supports. The variation of the cut strain and the moments (both bending and torsional) along the structure are taken as a formal reference for this project. The bridge spans an overall distance of 131 m, and it is split in three minor spans respectively of 34.50, 62 and 34.50 m. The main structure of the bridge consists of a series of three beams in reinforced concrete which are linked together at 11.5 m centre in the end spans, and six beams at 10.30 m centre in the central one.

Thanks to its symmetrical geometry, only six different beams were designed (they were replicated later for the other half). The overall width of the bridge section is 18.40 m and the double carriage is 13 m wide. The variable height of the girder is related to the changing cut diagram over the bridge. The upper part of the beam, at a constant thickness of 20 cm, constitutes the support of the carriage.

The lower slab, on the contrary, has a variable thickness because it contributes directly to resist to the bending moments. In fact, it has a minimum thickness at the extreme supports and a maximum one just over the pylons. Furthermore, Nervi designed the section of this structure in order to contrast the torsional moment, typical in bridges. The torsional moment is null at the supports while it is a maximum at the furthest section from the supports. If the width of this section is reduced, since the magnitude of the moment depends directly from it, thus the overall effect of the torque will be minimised. The bridge is linked to the two abutments and pylons (both in reinforced concrete) by a series of hinges, which allows the structure to accommodate to thermal effects.
Like in the majority of the structures conceived by Nervi, the original concept, derived by simple Physics considerations, is transformed into a unique, beautiful architecture. The sinuous profile, the technology and the building material reveal clearly the modern conception of the bridge, but, at the same time the bridge is also perfectly appropriate in the historical urban context. Again, this is achieved by the advanced, but still traditional conception of the structure, and by a certain attention to detail: concrete's grain and are perfectly in tone with the chromatics of the city of Verona. Another important is the choice of the local stone, *Pietra di Verona*, to clad the immersed pylons. This is at the same time a semantic (being at the 'base' of the new structure) and functional choice (because the stone cladding protects the steel bars within the concrete). All in all, a very similar approach to the one Nervi had in designing the sports buildings in Rome (with the quotation of the Pantheon *Oculus*). The attitude of Nervi in facing historical environments, here and elsewhere, marks a difference between him and other civil engineers. Nervi had a sensibility and a particular understanding of the urban context in its historical perspective. He developed this attention also because he had the choice to design in historical centers, where other engineers were employed to resolve infra-structural issues mainly in natural environments. Nervi challenged the architects in their territory per excellence: the City. Sometimes, he received him some harsh comments from the established culture of architects.

4. Designing a dream

After the construction of the Risorgimento, Nervi, in 1969, faced the ultimate challenge in terms of bridges: the Messina bridge, over the Sicily channel. This project has represented an unsolved issue in Italy in the last fifty years for many different reasons. Apart from any economical and political considerations, there are objective technical difficulties which have postponed the erection of the bridge. The spanning length of such a bridge is a challenge in itself. It is impossible to provide pillars along the Sicily channel, because of the depth of its waters (100 meters) and, more importantly, the strength of underwater currents. The only possible solution is a suspended single deck bridge. The supports have to be placed in two seismically active regions. If built, this bridge would be the longest suspended bridge in the world: 3300 meter in length, more than 66% longer than the current longest structure, The Akashi-Kaikyo Bridge (1991 meters).

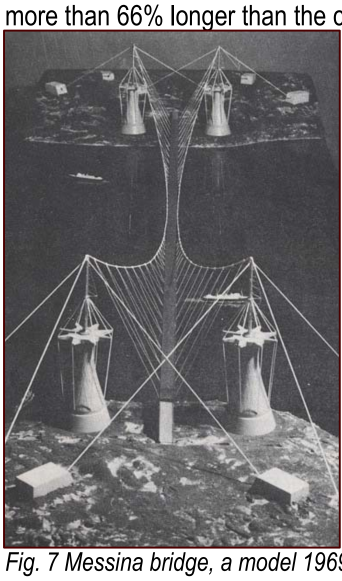

Fig. 7 Messina bridge, a model 1969

In facing this gigantic structure, Nervi was particularly concerned about the typical weakness of this kind of bridges: the limited transversal stability of the deck and its resulting torsional deformation due to the wind forces. Nervi believed that just giving an intrinsic transversal stability to the cables would result in an overall stability for the whole structure. In order to achieve this, he just changed the geometry of the cables. Instead of having the usual parallel cables which are co-planar to the vertical plane of the deck, he designed two skew cables, which have a parabolic projection both in the horizontal and in the vertical planes. Such a system was, in his opinion, absolutely wind proof. Of course, to be able to have such a geometry the four piers would have to be placed at a considerable distance apart fro one another. The two steel cables, designed with a diameter of 1.5 meters would link to the deck just at its centre. The four pillars were thought to be constituted from two different parts. The hollow base in reinforced concrete with a hyperbolic paraboloid profile, and an upper structure in steel of 10 m of diameter and with a thickness of 50 cm, whose the steel cables were attached.

The trapezoidal section of the deck is divided at three levels, a double carriage for automobiles, a lower level of service and cycle track, and a rail track on the lowest floor. The deck, designed in steel, is conceived as a triangular reticular to achieve the highest possible torsional rigidity.
For the same international competition, other engineers submitted their proposals, amongst them Sergio Musmeci, at that time the only Italian engineer who could stand in front of Nervi.
Musmeci's proposal, genial as usual, was something more similar to tenso-structure than a common bridge. In 1971, the commission assigned, ex-aequo, the first price to both the rival engineers. Nothing happened for thirty years. With the signature of the contract in 2006 between the ANAS (Italian highways department) and Impregilo, the company which won the competition, the bridge over the Sicily channel is again a matter of discussion. Over almost forty years, many things changed, not the last, the proposed location of the bridge.

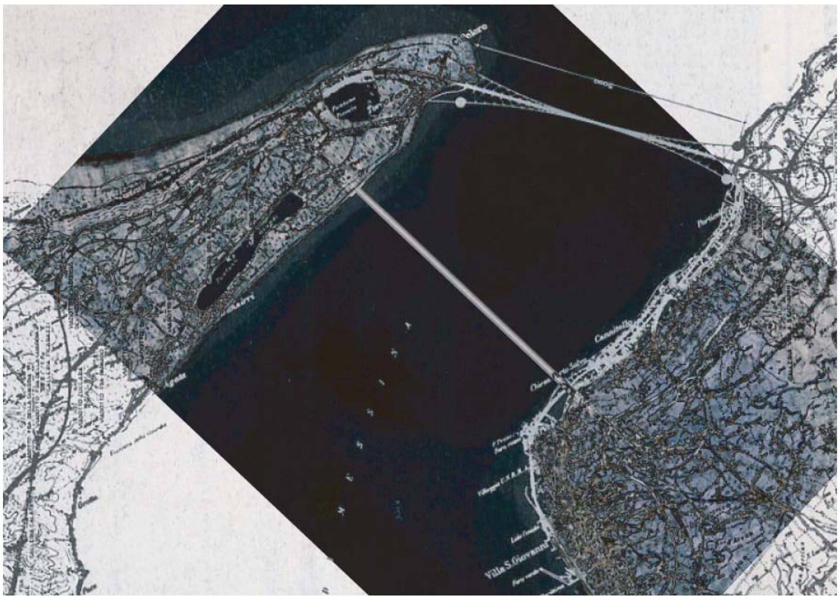

Fig. 8 Messina bridges, Nervi's proposal 1971 (top) and 2006

A comparison between the new proposal, and Nervi's and Musmeci's ones would be difficult, when one takes into account the development of steel technologies over almost half a Century. Certainly, in such a crucial debate, on the occasion of such an immense challenge the feeling is that authoritative voices like those of the two visionary engineers are missed.

5. Conclusions

Pier Luigi Nervi, mainly known as an outstanding builder of roof structures, was also involved in the design of several bridges. In considering this particular aspect of his production one can spot several similarities to other kind of structures:

- The only use of reinforced concrete in Nervi's early designs (bridge at Biedano, bridge over the river Tenza) and the later introduction of steel (Burgo paper mill, bridge projects in the USA)
- Nervi's particular attention in designing iconic structures in historical centres with particular allusion to the use of local and traditional elements (*Risorgimento* bridge in Verona)
- Nervi's initial reference to Physics laws to shape his designs and his subsequent work of refinement to achieve a aesthetically pleasant structure (*Risorgimento* and Messina bridges)

Such a similarities reveals once again how the great Italian designer approach different themes with the same *forma mentis*.

6. Acknowledgements and credits

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7. References

[1] Casabella 63 (1959) p. 54
[2] Nervi Pier Luigi, 'unpublished interview draft', *La Nazione*, June 1965
[3] MAXXI, Centro Archivi Architettura. Via Stanislao Mancini, 20. Rome.