

The recovery of the ethic of constructions: P. L. Nervi vs. S. Musmeci, two structural conceptions compared

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ABSTRACT: The works of two of the grandest engineers of the 20th century's Italian scene, inspire some remarks on the approach to the relations between the design and building practice, both from the creative point of view and everything concerning the theoretical and practical aspects. Pier Luigi Nervi and Sergio Musmeci are indeed two paradigmatic figures of structural engineer-architect who used the language of rational mechanics and structural engineering in very different ways, also with a careful look at the needs of image communication. Their figures respectively represent the constructive (*technics*) and the mathematical (*techniques*) dimension of the structural conception in architecture; the former concerning the influence of the structural language in realized architectures (forms), the latter related to the potentiality of calculus in the invention of new shapes. They differently aimed at the same target, trying to preserve some tectonic ethic in their creative workflow, leading the way to an effective convergence between *ars* and *techné*, form and structure, rigour and soul.

1 INTRODUCTION

At present, exploiting the wide possibilities offered by new sophisticated software, the design of new structural forms finds a significant propulsion. This onward process puts in front of the crucial question: how to manage and control the consistent computational-technological heritage in order to dominate and make best use of it, in agreement with the building practice?

In the actual electronic context and in the visual communication era (deconstructionism, non linearity, virtuality) is it possible that architecture still preserves a *tectonic* ethic, aimed at realizing the unity of the Vitruvian triad, not abandoning the communicative content of the realized work?

This work tries to give an answer by comparing two paradigmatic figures of structural engineer-architect of 20th century, Pier Luigi Nervi and Sergio Musmeci, who used the language of rational mechanics and structural engineering in very different ways, both with a careful look at the needs of image communication. On one hand Nervi (or the constructive dimension), who finalized his work to credit the role played by the structural-constructive component (*firmitas/tectonics*) in realized architectures by resizing the role of quantitative aspects in structural mechanics, often conceived as a limit for the creative invention. On the other hand Musmeci (or the 'mathematical dimension'), who aimed at recognize and valorize the less evident links between architecture, mathematics and scientific language tout-court.

2 MATHEMATICS AND STRUCTURES

The relations between mathematics and architecture move from the late past in which mathematics was essentially conceived as geometry. Until the renaissance era, the technical component (*firmitas*) completely informed the construction, while the mathematical language was, in a sense, part of the constructive process as geometrical support (Trovalusci, Pani, 2010).

In modern architecture, a close relationship between geometry and the architectural design, strictly related to the technological component, still stands, delimitating or exalting the final reconstructive result ('operative geometry'; Bellini, 2004). The adopted geometry is traditionally linked to construction problems, consisting in finding a way to realize a given geometric shape obtained by the exclusive use of the ruler, the compass and the set square. The final results are abstract forms, influenced by the utilised tools. The constructor vocation is mainly 'conformative' instead of 'representative' (De Fusco, 2003), but they do not need to use the language of arising new mathematic methods, as the differential calculus is. Designers grown-up in the mathematic world (Guarini, Wren) instead, use to refer only to the language of classic geometry.

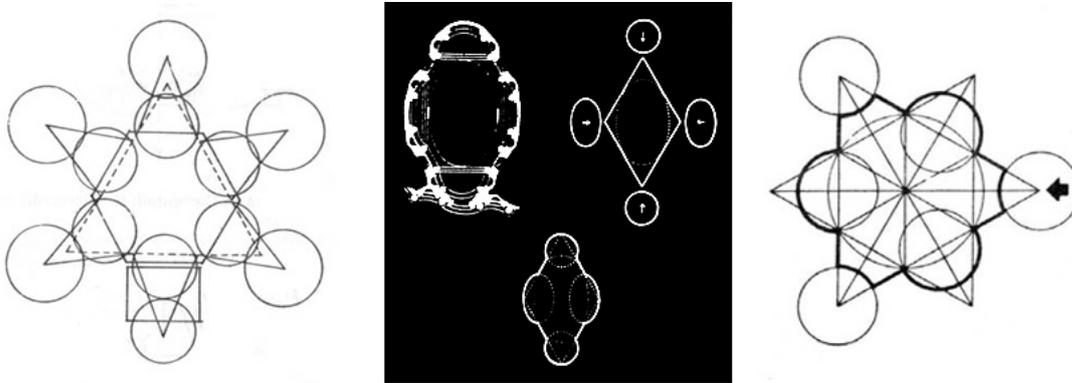


Figure 1. 'Operative geometry' in Borromini's work.

At the same time the new powerful mathematic language (calculus), widely developed in the 17th century, starts to be exploited for studying issues of architectonic design, like the search for the "best shape" of vaults (*velariae, laminae elasticae*; Benvenuto, 1981), or for stability criteria for constructions (Vatican dome, catenary solution; Poleni, 1748). At the end of 18th century mechanics is formalized in the mathematical language and ready to develop its applicative potentialities. But the "New Science" has to go through the whole century, dedicated to abstraction, before to have influence on the culture of constructors.

Successively, the industrial revolution provokes a radical transformation of the consolidated building technologies, effectively creating the need of a new professional figure: the structural engineer. That is a new generation of professionals who bases his knowledge on the theoretic background of analytic mathematics and rational mechanics applied to the solution of building problems. Mechanics and mathematics begin to grow together, aiming at the rationalization of the design process (Navier, Clapeyron, Maxwell, Mohr, Castigliano, Müller-Breslau, etc.).

Following this path the structural design became more and more sensitive to formal arrangements over years: the concept defined as *art of construction*, moved from the fence represented by empiric dimension, became *science of the art of construction* (Di Pasquale, 1996). The structural conception reached not only an awareness of methods, but also of models in structural design, became crucial for the invention of new shapes. However, the rationalization process of structural design caused the proliferation of mathematical models taught in the schools of Engineering, which, due to the laboriousness of calculations, led to the progressive lost of the unitary conception of designing, impoverishing the creative process. Designs developed in the schools of Architecture confine the creative invention in the virtual act of representation, disregarding the constructive aspects which, where necessary, were subsequently delegated to the insiders. This resulted in a strong dichotomy between design (representative component) and realization (conformative component). A dramatic divide, still existing.

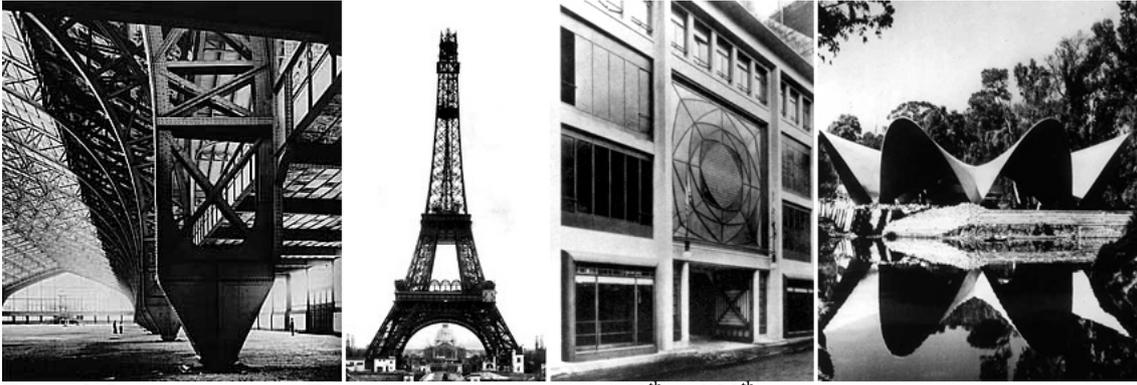


Figure 2. Iron and concrete. Examples of architectures of 19th and 20th centuries.

3 TWO STRUCTURAL CONCEPTIONS

The years in which Nervi works are years in which, after the large nineteenth-century development of the theory of elasticity, the structural engineering has acquired all the necessary tools of analytical mathematics and mechanics for the solution of the problems of construction. Thus providing a significant background of rational mechanics for structural mechanics.

However, in the overflow of computational needs Nervi recognized a growing lack of intuition and static sensibility in the education of structural engineers. He strongly denounced the scholastic division between architects and engineers, as the true cause of the crisis of contemporary architecture. His *tectonic* method, almost magnificently hand-crafted, is widely evident in the attention he use in the overall practical aspects of the building practice. Well-known are all the efforts he made to overcome all the financial and formal commitments caused by wooden formworks widely resorting to on-site prefabrication. It's worth noting how he developed a system able to enhance the aesthetic benefits resulting from iteration and repetitiveness of structural elements, declaring at the same time how the key to the problem solution is the removal, or the reduction, of those technological commitments.

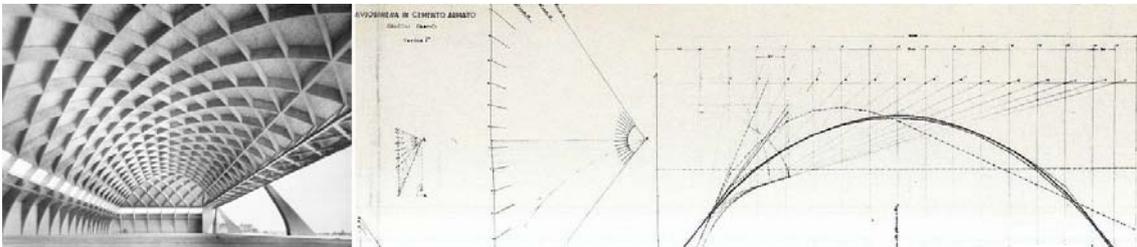


Figure 3. P. L. Nervi: *Hangar*, Orbetello, 1960. Graphical statical calculations (Desideri et al., 1979)

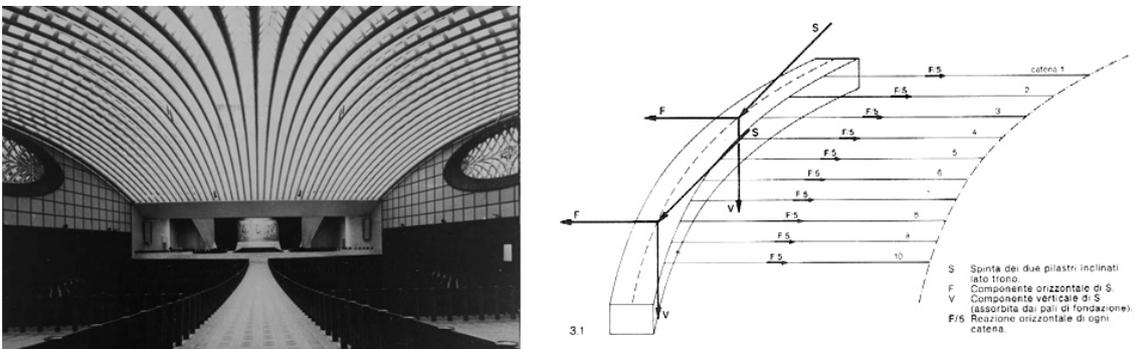


Figure 4. P. L. Nervi: Auditorium, Vatican City, 1966-1971. Graphical statical calculations (Desideri et al., 1979)

From the point of view of the structural calculations, he usually referred to simple mechanical models, like those used for the analysis of the structures of hangars in Orbetello (Fig. 3) and Orvieto. In any case, the mathematical apparatus of the new structural mechanics was deliberately avoided in the design phase and used only 'a posteriori' for determining the material strength.



Figure 5. Pier Luigi Nervi, modern poet of the concrete, under the Corso Francia viaduct

Conversely, Sergio Musmeci's work widely investigates the role of mechanical-mathematical language, that is the role of technique perceived as analytical instrumentation, in architectural design. His attention is focused on the design of new resistant shapes, inspired by nature.

Moving from the debate on the catenary and the studies of the seventeenth and eighteenth centuries on equilibrium of elastic membranes and shells, passing through the analysis of minimal surfaces, he introduced the necessity to extensively resort to the mechanic-mathematic background in architecture, pioneering the design of structures resistant by form, nowadays supported by the extended use of structural optimization algorithms.

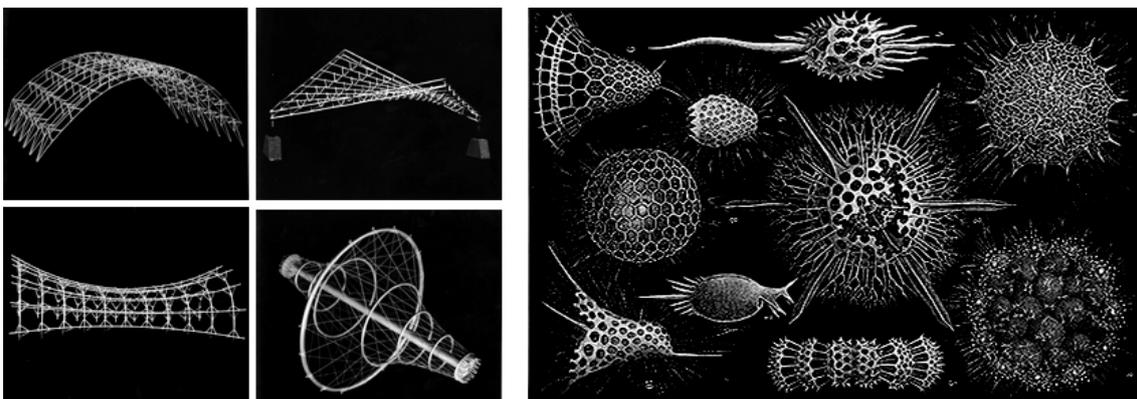


Figure 6. Shape resistant structures (Le Ricolais studies 1894-1997). Natural forms.

It is well known that this approach has been already investigated, from an experimental point of view, by Antoni Gaudì but, besides the experimental approach, he widely exploits the possibilities to use the differential calculus to design new shapes. He is not the only engineer in this field and many important figures can be mentioned, from Frei Otto, to Eduardo Torroja, Felix Candela, up to Eladio Dieste. But his peculiar point of view, strictly theoretically based, is originally based on the reduction of the role of the empirical intuition, opening to contemporary research on optimal design, with particular reference to the so-called 'form-finding' processes: *"it's impossible to be satisfied by a design method confining the use of rational tools to the mere verification process, leaving the shape creation phase to gratuitous design choices, or be-*

ing served by the sole experience” (Musmeci, 1979c, p. 40). Differently from Nervi’s approach based on the verification of structural strength check, this led him to develop a guideline focused on structural design based on the shape search, “tractions are not unknown, shapes are”.

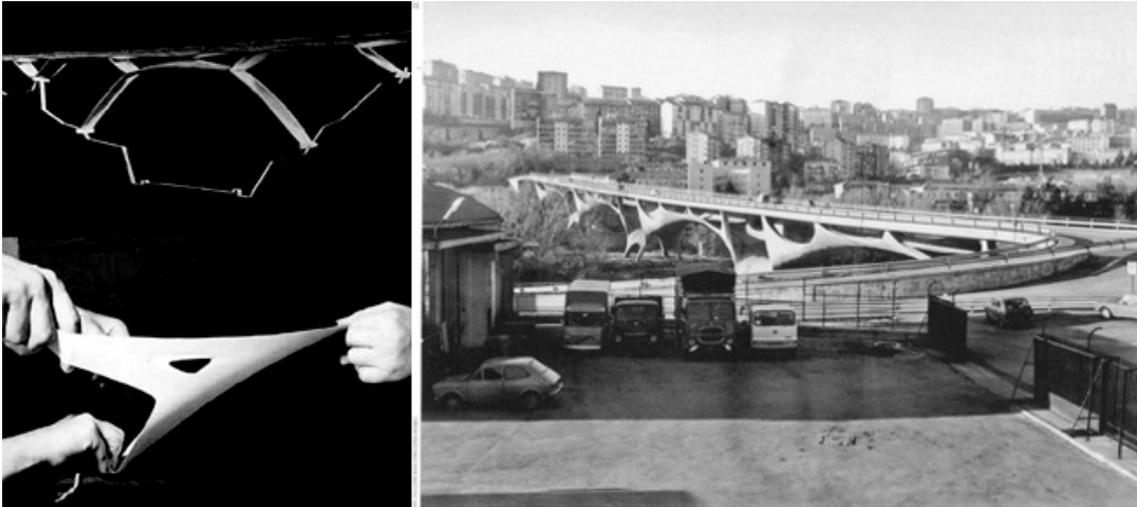


Figure 7. Experimental studies (rubber models) for the Basento Bridge (1967-1976, Potenza, Italy).

As already observed, this approach opens to Mitchell’s studies of topological optimization, well known by Musmeci and widely applied in his practice. It must be noticed, however, that Musmeci’s mathematic conception is not contraposed to the tectonic ethics of Nervi, because it is also provided of exquisite craftsmanship applied to the most proper qualitative aspects of the art of building.

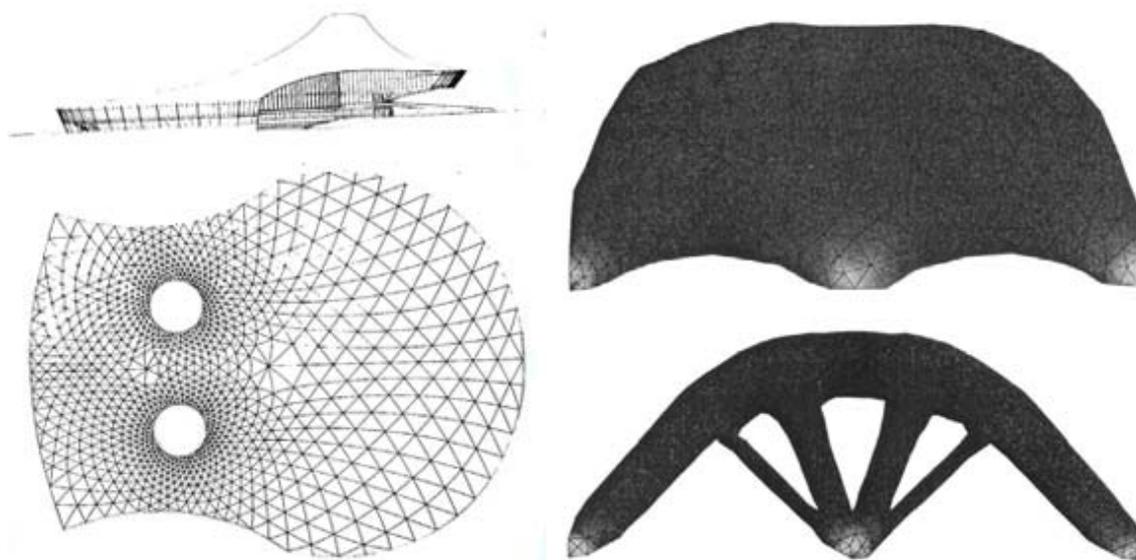


Figure 8. (a) Musmeci’s Florence Sport Palace: design (Musmeci, 1979c). (b) Mitchell’s beam.

The possibilities offered nowadays by mathematics, that is essentially numerical calculus, increase the design capabilities to think about new structural shapes, even in a direction which goes beyond the requirements of optimal structural performances, so far from Musmeci’s lesson itself. This happens mostly because of the wide diffusion of algorithms for the generation of purely geometric shapes. Innovative forms creation, which in the past eras was often entrusted to the technological invention (*technics*), by the result of a substantial correspondence between conception and execution, seems today entrusted to the mathematical-numerical instrumentation provided by the software (*technique*).

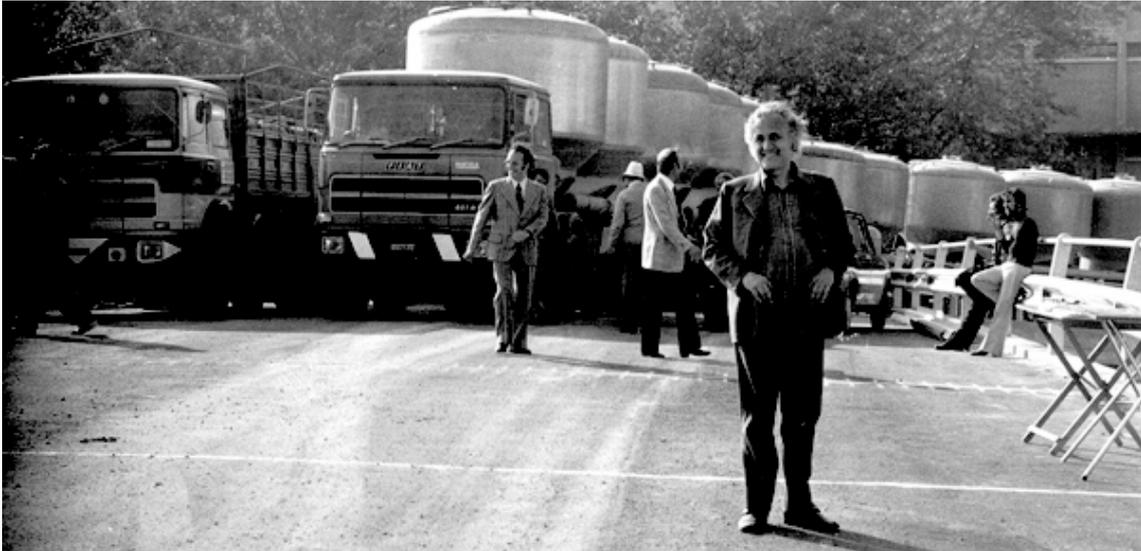


Figure 9. Sergio Musmeci, Basento Bridge testing.

Creativity is instrumentally more free, structural analysis codes allow to overcome the heavy computational costs lamented by Nervi, but the dichotomy between designed and realized architecture is more and more evident. In particular, the progress reached in the innovative designed shapes is not met by a real progress in building technologies. In most cases traditional technologies are employed, with very expensive working charge. Besides the building difficulties, the shapes proposed rather than being innovative, paradoxically, often fall into a repetitive figurativity.

With a view to regain the correspondence between new designed shapes and realized forms, the actuality of Nervi's lesson emerges today in all its evidence: we need to design the realization.

4 FINAL REMARKS

With the comparison between these two structural conceptions, *technics* versus *technique*, we want to indicate a possible work direction not transcending any of these elements. As already mentioned, we need to understand how, in today's electronic and visual communication age, architecture can preserve a tectonic ethic.

The optimization procedures, allowing us to remark the role of the structural component (with obvious practical advantages), should be preferred, by taking advantage of the mathematic-numeric instrumentation, offered by the use of CAE software, and the related suggestions for new shapes invention.

This providing that the role of the designer, perceived as a harmonizer of the various instances of design, remains central. Although in a completely transformed framework, we still have to recover the unitary conception of the design process understood as a synthesis of all the Vitruvian components, thus preserving what was one of the main taken of the lesson of the Modern Movement.

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