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Pier Luigi Nervi: an engineer, an architect and a builder

Pier Luigi Nervi: ingeniero, arquitecto y constructor

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ABSTRACT

All Nervi's works bear the stamp of his unique qualities as an engineer.

At the same time, they were always closely related to the cultural and social conditions both domestically and worldwide, which changed consid-erably during his long working life (from twenties to seventies): from World War One through the Fascist era to the enthusiastic second post-war reconstruction period, and on to the booming years of economic euphoria up to financial crisis of the seventies.

For this reason, upon reviewing his works, it seems to us that Pier Luigi Nervi lived not one but three lives in that he was a modern architect, a builder creator of a new building method, and an international star-architect.

Three equally intense lives that coexisted, overlapped and interacted but remained independent of each other. This paper tell briefly about the three lives of Nervi.

Keywords: Construction history; Pier Luigi Nervi; History of Structural Engineering; Made in Italy.

RESUMEN

Todos los trabajos de Nervi llevan el sello de sus cualidades únicas como ingeniero.

Al mismo tiempo, siempre estuvieron estrechamente relacionados con las condiciones culturales y sociales, tanto a nivel nacional como mun-dial, que cambiaron considerablemente durante su larga vida laboral (de los años veinte a los seten-ta): desde la Primera Guerra Mundial, pasando por la era fascista, hasta el entusiasta período de reconstrucción de la segunda posguerra, y los años de euforia económica hasta la crisis financiera de los setenta.

Por esta razón, al revisar sus obras, nos parece que Pier Luigi Nervi vivió no una, sino tres vidas en la que fue un arquitecto moderno, un constructor creador de un nuevo método de construcción y un arquitecto estrella internacional.

Tres vidas igualmente intensas que coexistieron, se superpusieron e interactuaron pero permanecieron independientes entre sí. Este artículo habla brevemente sobre las tres vidas de Nervi.

Palabras clave: *Historia de la construcción; Pier Luigi Nervi; Historia de la ingeniería estructural; Made in Italy.*

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In 1958 Pier Luigi Nervi gave the conference celebrating the 25th anniversary of the ITTC. He began his lecture with these words:

> "Le agradezco mucho a mi querido amigo el Profesor Torroja la gentileza de haberme hecho venir aquí para este acto, porque siempre he admirado este Instituto como una síntesis verdaderamente notable de la ciencia y de la belleza" (1)

This paper is dedicated to the friendship between Torroja and Nervi.

1. INTRODUCTION

All Nervi's works bear the stamp of his unique qualities as a design engineer. At the same time, they were always closely related to the cultural and social conditions both domestically and worldwide, which changed considerably during his long working life (from twenties to seventies): from World War One through the Fascist era to the enthu-siastic second post-war reconstruction period, and on to the booming years of economic euphoria up to financial crisis of the seventies. For this reason, upon reviewing his works, it seems to us that Pier Luigi Nervi lived not one but three lives in that he was a modern architect, a builder creator of a new building method, and an international archi-star. (2) Three equally intense lives that coexisted, overlapped and interacted but remained independent of each other. Telling briefly the three lives of Nervi, it's also possibile to collect elements about some key questions: how is his work (as a whole) in engineering and architec-ture of the twentieth century placed? What influence does it assume after his death? How could the current great interest for his architec-ture be explained?

2. NERVI'S FIRST LIFE

Nervi lived his first life as a modern architect (with more than a hint for futurism). That was the time when, after applying the methods of reinforced concrete building construction for years, at the age of forty Nervi designed and built the Berta Stadium in Florence, which would soon be recognized as a masterpiece of the new Italian architecture. As a result, Nervi found himself projected into the debate over modernity that was raging in Italy under autarky.

The reinforced concrete structure was always the centre of Nervi's activity since his dissertation. As a site manager for Attilio Muggia's construction enterprise, he was in charge of the building of numerous, complex structures (Attilio Muggia was his master and also a Hennebique agent). Then, as owner of the Nervi & Nebbiosi building business, his first company, Nervi designed and constructed the roof for the Banchini Theatre in Prato and the "structural machine" for the Augusteo Theatre in Naples in 1925. They were all new and modern reinforced concrete structures, but were hidden behind the tradition-al, eclectic architectural language.

At that time, there were still uncertainties and doubts on the calcula-tion methods to be applied for large-scale works made with the new material. While carrying out experimental studies on the construction site, the young Nervi discovers his intuitive ability towards the static behavior of structural forms. Above all the complex and highly hyper-static structure, which the classical theory of elasticity does not allow for rigorous calculation.

Nervi's ingenious intuition of the inherent properties of reinforced concrete would emerge clearly with the design of the Berta Stadium with its unexpectedly exposed structures (out of very practical reasons: they had run out of money for finishings). The frame-mounted terrace, the 22-m cantilever roof, the spiral staircases and the Maratona tower were soon regarded as original examples of modern architecture. On leading Italian and international journals, the stadium was judged (by Giedion, for example) as a sign of "Italian revival" on the way to modernism.

In the wake of success, Nervi found himself involved in the debate over autarky and innovation, perhaps unaware that he would become one of the reference points. He joined in by writing articles dealing not only with structural design issues on magazines like "Quadrante" and "Casabella". He designed a series of futuristic-inspired plans, neither of which was to be accomplished. One of them regarded a floating hotel and was based on an ingenious method to reduce the intensity of wave action and achieve stabilization. The Flag monument was a slender tower, 250 m high, which was stabilized by suspending a heavy pen-dulum on its top. The revolving house would track the sun's position to maximize the amount of sunlight used to light the various rooms. The Water and Light Building and the weakly-reinforced concrete Monu-mental Arch were among the numerous visionary proposals put forward for the construction of the E42 District in Rome (now called Eur).

Nervi's participation as a prominent figure in the architectural debate was brought to a close on the outbreak of war, which concludes his first life. In the meantime, actually, Nervi had already turned to new, more challenging experiences in his private firm.

3. NERVI'S SECOND LIFE

This is the long, adventurous period when he was a curious experi-menter and a great constructor. Between the Thirties and the first half of the Sixties, he would first invent the so-called Nervi System, a completely new way of designing and constructing reinforced concrete structures, and then apply it to the marvellous masterpieces of his maturity. It was an extraordinarily effective, quick and economic method whose stamp would be unmistakably seen in the original architectural design of his structures.

While the debate over autarchy was raging, Nervi went back to explore the unknown potentialities of reinforced concrete by designing some airplane hangars for the Italian Air Force (the first were built in Orvieto in 1936). He set up a new business, the legendary Nervi & Bartoli, and concentrated on the creation of a very complex and innovative framing system: the load bearing structure consisted of two series of arches that were rotated with respect to the imposts of the cloister vault and intersected one another. That design solution would allow him to exploit fully the potentialities of reinforced concrete, and above all its monolithic nature. He overcame the inherent difficulties related to complex mathematical calculations needed for hyperstatic structures first by intuitively estimating their static behaviour (by breaking the whole structure into simple isostatic systems) and then by carrying out accurate tests on celluloid scale models. This was an absolutely new approach in Italy. They were the first 3D scale model trials. They were carried out in the laboratory

that Arturo Danusso (the scientist who worked closest with Nervi) had created a few years earlier (in 1931) at Milan's Regio Politecnico.

While exploring new approaches to structural design, with the construction of the airplane hangars the Nervi & Bartoli building business turned into an actual laboratory where experimental research on new construction methods was carried out.

In Nervi's opinion, reinforced concrete was not a codified building technique, rather a construction strategy that could still be improved, enhanced or integrated by other inventions since it was in the early stages of its development. It was in the war years and when autarky was prevailing that the Nervi System was improved. The new construction process to build reinforced concrete structures was based on two inventions.

The first invention was called structural prefabrication by Nervi him-self, and was introduced in 1940 when the second series of airplane hangars was built (six buildings located in Orvieto, Orbetello, and Torre del Lago). Both series featured arches overlapping one another, but while, in the first hangars, they had been cast on site, in the second they were prefabricated in little portions, then assembled into place, thereby restoring the monolithic conformation and structural continui-ty of the whole.

The second invention was ferroconcrete, a composite material consist-ing of layers of wire mesh embedded with dense concrete incorporating fine fillers. It was actually a genetic variant of the reinforced concrete developed through subsequent patents between 1943 and 1945. The new compound, discovered while working on the construction of some fishing boats, showed homogenous properties and allowed construction of complex, thin surfaces without the use of any formwork.

After World War II, the strategically combined use of structural prefab-rication and thin ferroconcrete slabs, that is the application of the Nervi System, turned out to be particularly suitable for constructing large domes with basic equipment and simple building techniques. Actually, the use of ferroconcrete allowed to cast small and lightweight blocks on the building site and to place them in position with the support of light, movable scaffolds; that would make it possible to mould structures having great inertia, undulated or ribbed surfaces, thereby getting the most out of the inherent resistance of form (not just overall but also in each and every section). Nervi & Bartoli tested the system on various minor works before applying it to large-scale works in the years leading from reconstruction to the economic boom.

The first work was the Hall B at the Turin Expo, designed in 1947, where a barrel vault with a 90-m span was produced with small "wave blocks" in ferroconcrete of only 3 cm thickness prefabricated manually on site.

Then in 1951 came the unmistakable ceilings of the Gatti Wool Factory in Rome, with ribs following isostatic lines produced with ferroconcrete formworks.

The peak was reached with the construction of the 1960 Rome Olympics works. In a short time the Nervi & Bartoli realized four great works: the Palazzetto dello Sport, Figure 1, with its

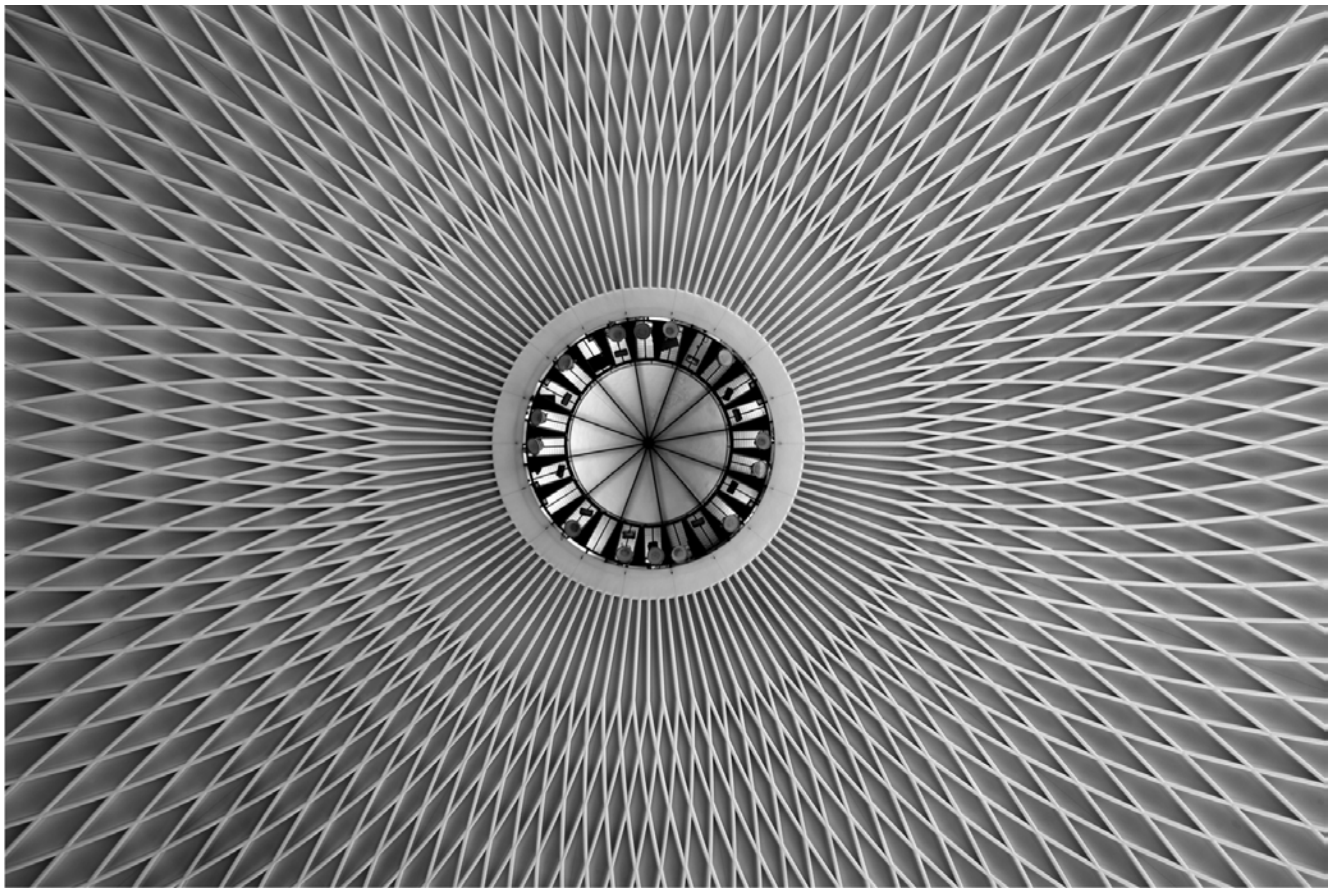

Figure 1 – Little Sport Palace at Flaminio, in Rome (Photo Sergio Poretti, 2014).

flat dome supported by a carousel of trestles (3); the Palazzo dello Sport at Eur, Figure 2, roofed with a finely undulating dome of 100 meter in diameter (4); the Stadio Flaminio with its elegant canopy (5); the Corso Francia viaduct, with its characteristic variable- section pillars (6).

The large domes, particularly, represent the most complete result of the Nervi system. They seemed to have been modelled on giant mould but were actually built by joining together small pieces precast on-site.

3.1. An investigation into Nervi's worksite

The best way to understand fully the nature of the Made in Italy as intended by Nervi is to follow step by step the construction history of one of the masterpieces he designed and built for the Rome Olympics: the Palazzetto dello Sport (7).

In 1954, the Italian National Olympic Committee (CONI) commissioned the design of a prototype medium-sized sport facility to be replicated in every Italian city. The building had to be very simple and cost-effective. Nervi (with Annibale Vitellozzi) proposed a project whose estimated cost was incredibly low: 200 million liras (around 2.5 million euro, today). The final design was really basic: a flattened dome (only 10 m in rise) having a circular plan, 60 m in diameter, supported by thirty-six Y-shaped radial inclined trestles spaced 10 degrees apart. The estimated low cost of the project was based on the use of the Nervi system.

The first stone was laid on June 27, 1956. The works would have to be completed in just 420 days since, in the meantime, Rome had been assigned the organization of the 17th Olympic Games. After excavations, the prestressed foundation ring was prepared. Then, the circle of radial trestles was created by applying the traditional cast-in-place technique. In order to reduce costs, only two formworks were used. However, the construction process was judged to progress too slowly by the CONI representative. After a quick site inspection, on November 8, he sent Nervi & Bartoli a reminder in which, in a harsh tone, he ordered them to speed up the construction of the building.

The annoyed, short replay by Nervi was that actually the work was almost finished!

The careless CONI representative had not realized that another build-ing site had been set up next to the site where ordinary concrete elements were cast. The dome was being created there, by applying the Nervi system.

The dome was made up of 1,620 small, rhomboidal "tavelloni". Overall, 13 different types of blocks that, once assembled in place, would create the dome as if it were a huge mosaic. Each hollow block was small enough to be made by hand and moved by two labourers. That was the key issue that would make the whole system so cost-effective: that way the expensive, continuous wooden support was no longer needed.

What made that painstaking manual process so extraordinarily cost-effective was an ingenious 'generational' solution that allowed produc-tion of around 30 "tavelloni" per day with the certainty that each of them would fit exactly in the final assembly.

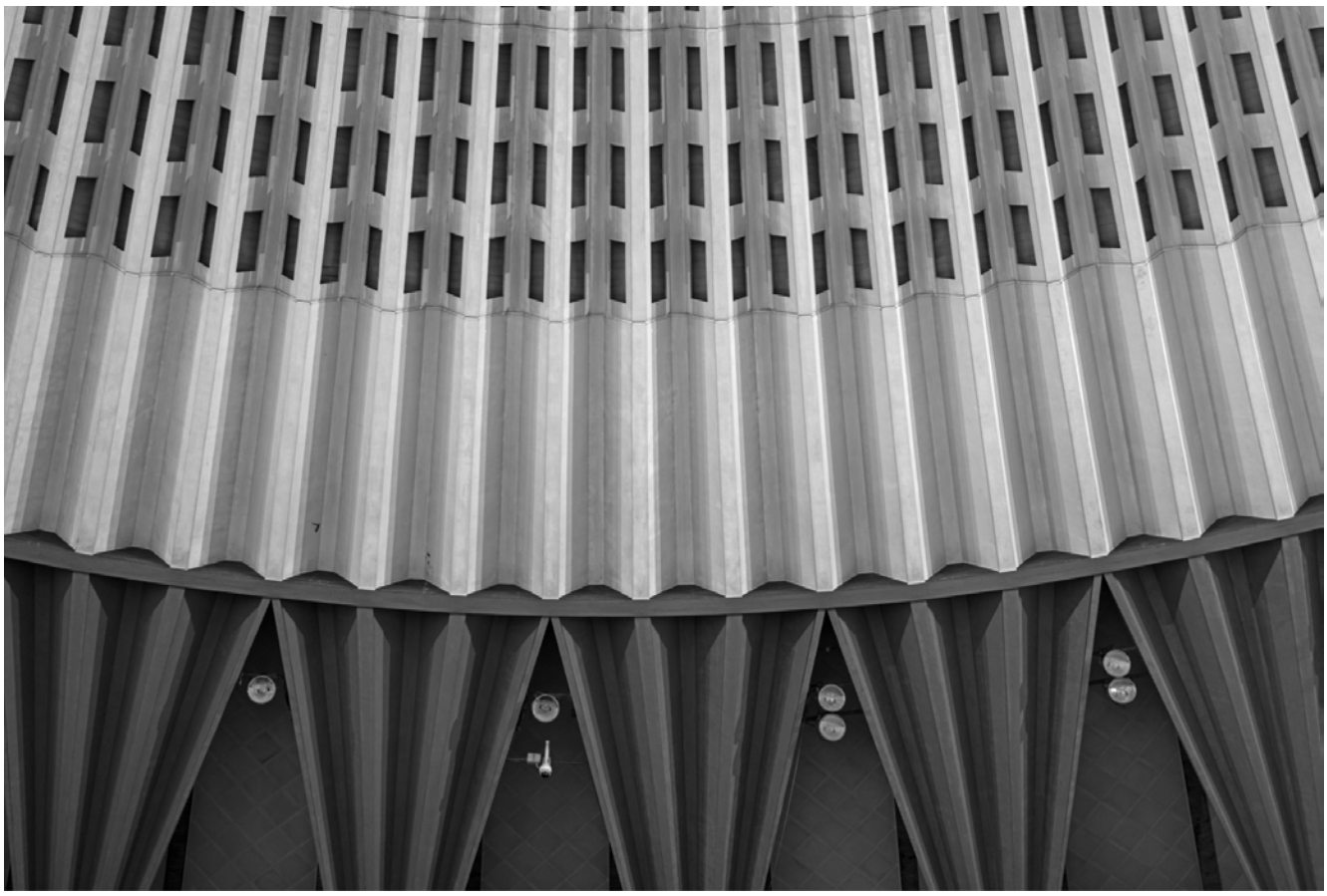

Figure 2 – Sport Palace at Eur, in Rome (Photo Sergio Poretti, 2016).

First of all a wooden template had to be made that would replicate a segment of spherical dome. On this profile, then, after drawing the axes, 13 different masonry moulds would be made.

Each mould would then be used to make a ferroconcrete prototype block. This consisting of layers of fine rods and wire mesh, over which a 2.5 cm thick layer of dense concrete incorporating fine fillers was applied.

To replicate 108 times each of the 13 prototypes, Nervi created a precise sequence of steps: by turning the first block, called 'grandmother', upside down he would obtain a small number of 'mothers'; the mothers would then be brought into a warehouse where several labourer teams would use them to produce tens of 'daughters', that would be eventually used in the construction process (the generational terminology belongs to the real site jargon).

At the end of December 1956, all precast blocks were ready and stockpiled near the by now completed circle of trestles.

The blocks were placed next to each other on a lightweight, movable "Innocenti" scaffold (8). Then, once the puzzle was completed, reinforcements and concrete were used to fill the gaps between the "tavelloni". The dome would eventually look like a monolithic, cast block, and no one would ever tell that it was the result of the disassembly/assembly shown by the final project designs and site photographs. Block assembly required only 30 days. So on February 24, 1957 the dome was completed and opened to the first ecstatic visitors, much earlier than expected and within budget limit.

In the few years of the economic boom, other masterpieces had built by Nervi & Bartoli: the Palazzo del Lavoro in Turin, on the occasion of Italy '61 (9); the Pirelli Tower, in the memorable collaboration with Gio Ponti; the Cartiera Burgo a Mantova (10), with its characteristic bridge structure (and the minor raised tank for the FIAT in Turin). (11)

Such an impressive series ended with the construction of the Paul VI Audience Hall in the Vatican City: a daring masterpiece in which the lengthwise undulated structures converge toward the Papal throne changing continuously their geometry. The vault is made with a valuable mixture of white cement and white Carrara marble chippings.

So, where does the unanimously recognized originality of Nervi's work come from, especially in that central phase of his career? The ingenious intuition of the great structural potentialities of thin vaults, by keeping in mind that their resistant virtues depend on the form, is internationally recognized: since the Thirties it produced a series of trials by Torro-ja but also by Dischinger, Finsterwalder, Freyssinet, and in the post-war years, it was the basis for Candela or Isler's hypar shells. The signa-ture feature of Nervi's vaults, domes, ceilings lies essentially in the folded (pleated), ribbed, undulated structure of the surfaces. That is the distinctive feature of Nervi's architecture, which can, therefore, be seen more clearly from the inside.

Paradoxically, however, the exceptional nature of Nervi's works (and hence their Italianness) lies in their being complex structures made by using a simple and plain method invented by Nervi himself. That is closely related to the year-long technological underdevelopment the Italian building sector would experience from the reconstruction years to the first half of the Sixties. Not only current building but also large-scale infrastructures were still constructed in substantially pre-industrial building sites by small-sized enterprises that used very little automated equipment.

The Olympics in Rome, the first broadcast on television around the world, enhances the international dissemination of the work of Nervi. The unmistakable image of its structural architecture became one of the icons of the Italian Style: perfect (and also monumental) example of the Made in Italy's image, the creative use of ingenuity to make the most out of available resources.

4. NERVI'S THIRD LIFE

That was the time when Nervi became an ante litteram international archistar. At the same time as he was fully involved in experiments with the Nervi & Bartoli business, around the mid-Fifties he started a new activity: he established his own architecture and design studio - Studio Nervi - that would work with an international clientele. From a historical point of view, the works developed by Studio Nervi for build-ings to be made in foreign countries have to be distinguished from the works constructed in Italy by Nervi & Bartoli, even though in reality (and according contemporary monographs) both activities intermingled closely.

First of all, in the works designed by Studio Nervi, the old engineer was no longer a constructor but confined himself to merely acting as a designer, and most projects would be carried out in collaboration with other foreign construction enterprises. Further, he was sharing the responsibility of his business with three of his four sons: Antonio, the eldest, was an architect, and since 1950, he was his father's most reliable assistant (and together they would sign most projects); Mario, an engineer; and Vittorio, the youngest, himself an architect.

The beginning of Nervi's international activity can be identified in the design of the Unesco Headquarters in 1952. Three designers were selected: the American Marcel Breuer, the Prix-de-Rome-winner Bernard Zehrfuss and Nervi. The far from minor role that Nervi played in the project design can be seen very clearly in the conference hall with densely ribbed, form-resistant slabs. While since the early Seventies Nervi & Bartoli had gradually been approaching a point of no return because of the national building industry being in dire straits, the Studio would keep growing and by May 1972 counted 25 employees (which was extraordinary at that time in Italy). Opportunities of designing large-scale works abroad had been multiplying from the very beginning. The construction of the Unesco Headquarters was not yet completed when Nervi began working on a first design for the Centre National des Industries and Techniques (CNIT), which would never be built. Then came the design of the George Washington Bridge Coach Terminal in New York (12); the Stock Exchange Tower at Place Victoria in Montreal, designed together with Luigi Moretti; the Australia Tower in Sidney, designed with Herry Seidler. And again in the second half of the Sixties: St. Mary's Cathedral in San Francisco, designed together with Pietro Belluschi; the Sport Palace in Norfolk, Virginia; the indoor stadium and ice skating arena in Darmouth (13); and, above all, the Italian Embassy in Brasilia (14).

What are the distinctive features of the works designed by Studio Nervi worldwide? How do they link up with Nervi & Bartoli's experimentation in Italy? To what extent do those buildings maintain the identity of Nervi's most orthodox works and his building method?

Overall, the Studio's production seems to be more heterogeneous than Nervi's Italian works. That was the natural consequence of many differences: his customer's heterogeneity, his partial role in the design, and different relationships with numerous foreign building firms. However, such heterogeneous production shows also the continuous effort by the Studio's designers to keep the main features of the Nervi system.

For instance, ribbed or undulated surfaces, not only in the oversized dome of St. Mary's Cathedral, but also in the New York bus terminal, and the dome of the Norfolk Sport Palace.

And again the monumental shaped pillars, in the central part of the Coach Terminal, as support to St. Mary's roof, and in the plastic columns of the Norfolk dome.

However, the distinctive features of the Nervi system take on a different connotation in the international works designed by the Studio. Without the construction stage on site, detached from the peculiar situation of the Italian building industry in which they were developed, they would undergo an 'encoding' process. On an international level, the typical building technique of the Nervi system turned into a style. The so-called Nervi Style.

5. WAS NERVI A FOLLOWER OR A FORERUNNER?

What do the differing works in three lives of Nervi share? A main trait unites the works of futurist architect, of Italian constructor, of international star-architect: absolute fidelity to the "minimum principle" according to its classical Galilei's interpretation of 'uniform resistance'. More specifically: the belief that the potential of reinforced concrete can make the most out of that principle.

As Nervi said: "*Adaptability to any form and the capacity to resist all three major stresses make reinforced concrete the most revolutionary material in the history of the construction industry [...]The possibility to create cast stones of any form, which being more re-sistant to stress are better than the natural ones, is somewhat magic*".

However, that is not enough. It has to be completed by the firm belief that the "Economy principle", a principle that in modern engineering represents extreme rationality, ensures also 'beauty'. In other words, the belief that by respecting the principles of ethics, esthetical principles are reached. The monolithic structures of the domes with their rich and thick drawing actually highlight the balanced distribution of forces so that it appears as a "revealed truth".

It is the structural honesty postulate, enhanced, in Nervi's case, by the construction honesty postulate. This way the artefact gets closer to Nature. However, on such a critical issue Nervi has something to say:

"The distribution of forces within a hyperstatic system [...] is a perfect model of justice and distribution of economy, of which we can only vaguely grasp its mysterious and divine wisdom."

What happened to Nervi's work after his death? Nervi's architecture died with him. Why? As outlined, the way it was born was closely related to the conditions of proto-industrial Italy, which changed abruptly after the booming years of economic euphoria. In the follow-ing years, Italian engineering, after having been the second most repre-sented (after the United States) at the "*Twentieth Century Engineering*" Exhibition at New York Moma in 1964, completely vanished. At the same time, the more general transformation in the role of the structural designer completed. By adopting such a historical perspective, Nervi is an epigone of the nineteenth-century engineer in that he owned the numerous scientific skills, both technical and artistic, that those who built large-scale works had to own. This quality is anachronistic today, where large structures require a multidisciplinary team of specialists. At present, though, that diagnosis cannot be sufficient.

In recent years, Nervi has made a powerful comeback, and his work is the object of studies, researches, exhibitions: there is a true Nervi boom. In 2010, on the occasion of the exhibition organized by Maxxi Museum in Rome, Zaha Hadid has publicly recognized him as one of her teachers. How can all this be explained? When considering historical distance, Nervi's architecture shows a sort of innermost double-ness. It is one of the most striking examples of the great nineteenth-century tradition of modern engineering and, at the same time, includes some prophetic predictions on current post-modern (and post-industrial) research: informal, deconstructivism, and the like. It is not only Nervi. In more general terms, it is the glorious Sixties' generation of Italian engineers (also Morandi, Zorzi and above all Musmeci) that has a striking influence on present experimentation. (15) The mysterious reasons behind this phenomenon could be the object of a future debate. In the meantime, a bitter note: unfortunately, in today's scenario of international experimentation so strongly influenced by Nervi and company, current Italian engineering is conspicuous by its absence.

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