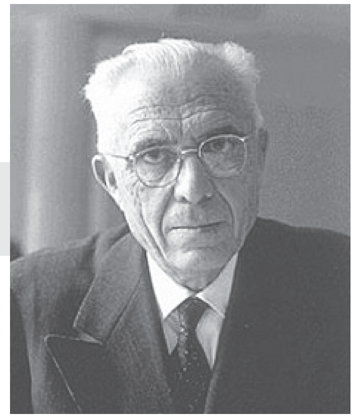
Pier Luigi Nervi: The Grand Master of Concrete Structures



Pier Luigi Nervi (1891-1979) is one of the greatest and most inventive structural engineers of the 20th century. He shared the cultures of architects and engineers, operating at the very intersection between the art and the science of building. With his masterpieces scattered the world over, Nervi contributed to create a glorious period for structural architecture. At the ACI American Concrete Institute Spring 2012 Convention in Dallas, TX in March, Professor Mario Chiorino of the Politecnico di Torino (Turin Institute of Technology), Italy, illustrated Nervi's work and discussed his basic philosophy of structures within the ACI International Lunch keynote lecture entitled *"Art and Science of Building in Concrete: the Work of Pier Luigi Nervi"*. The lecture, whose synthesis was published in the March issue of ACI *Concrete International*, was related to the general convention theme *"Art of Concrete"*. In an email chat with ICJ Professor Chiorino further considers some of these themes.

ICJ: We understand that you have deeply analyzed in recent years Nervi's figure and work, also in connection with the international travelling Exhibition "Pier Luigi Nervi: Architecture as Challenge" for which you act as a member of the Scientific Committee for the aspects concerning structural concrete. Not many younger concrete enthusiasts in India would know about Nervi. For the benefit of this section of scientists, engineers and architects please describe Nervi .

Professor Chiorino: Nikolaus Pevsner, the great architectural historian who is best known for his studies on Modern Movement and his guides on British architecture, described Nervi as *"the most brilliant artist in reinforced concrete of our time"*.

The true art of Nervi is his ability to combine art and science, imagination and techniques in a way that enables him to transform structural concrete into a kind of visual poetry. However, in the conversion of his inspiration into a design and of the design into a construction he does not renounce to the modus operandi of engineers, but rather emphasizes it with original and innovative contributions. His struggle for freedom in design, which in those times was confined by the lack of modern computerized structural analyses, was also the principal justification for his keen interest in experimental research, especially on mechanical scale models.

Nervi's personality comprised many facets, including designer, builder, researcher, and creator of new construction techniques. He was also a Professor and Lecturer at prestigious universities around the world, and author of books debating the conceptual and technological fundaments of construction, with particular regard to concrete construction.

He has been described as having an engineer's audaciousness, an architect's imagination, and a businessman's practical realism. His use of the most advanced technical solutions always went hand-in-hand not only with the pursuit of formal elegance but also with an equally strong attention to the technical and economic aspects of the building process.

ICJ: Could you describe Nervi formative years?

Professor Chiorino: Pier Luigi Nervi was born in Italy 1891. He graduated with a degree in civil engineering from the University of Bologna, Italy, in 1913. Incidentally, this decade was a fertile period for scientific, technical, and architectural ideas, as the new technology of reinforced concrete was fast developing at the dawn of the 20th century. That period saw many a contribution from pioneers such as Wayss, Hennebique and Maillart. From the very beginning, the new field was associated with a conscious search for artistic results.

It is against this background that Pier Luigi Nervi's professional career began. After an initial period of training in the technical office of a construction company, Nervi set up his own design and construction business in 1920. Nervi was to maintain this dual role of designer and builder throughout his life.

ICJ: Can you name a few of his early construction projects?

Professor Chiorino: Yes. There are many. For example, the stadium in Florence built in 1930 was Nervi's first great work. It attracted the attention of critics and the public—both in Italy and abroad. The stunning design is characterized by the elegance and strong visual impact of the curved tapered corbels of the cantilevered roof and the spatial sculptural forms of the helicoidally warped stairs. It is interesting to note that from among the many other designs, Nervi's design was chosen chiefly because of the low construction cost.

Some other great examples are a series of hangars designed and built for the Italian air force at Orvieto and Orbetello in the years 1935 to 1940. Probably influenced by the design of hangars and temporary exhibition halls constructed primarily in Germany in steel and laminated wood, Nervi conceived a daring, yet dramatically simple in structure, wide geodetic roof with intersecting arched ribs.

It should be observed that while he built the first group of hangars using traditional scaffolding and wooden forms for the concrete structure, subsequently the building technique was drastically modified. He used ribs consisting of precast elements that were connected on-site. From that time on, the use of precast components would become a constant in Nervi's work, as he sought to exploit and maximize the outstanding compositional and structural freedoms offered by prefabrication.

ICJ: We understand Nervi used ferrocement in some of his projects. Which projects of his had ferrocement and what inspired him to use this material?

Professor Chiorino: Ferrocement technology had been originally adopted in France by Jean Louis Lambot in 1846, at the very dawn of reinforced concrete technique, to produce a "ferciment" boat hull. The hull comprised a thin layer of concrete reinforced with a thick mesh of small-diameter wires, and it exhibited remarkable ductility and resistance to cracking.

After using it for an experimental warehouse at the site of his construction company at La Magliana, near Rome, Italy, in 1945 and, also in his case, for the hulls of small ships, Nervi used ferrocement in his first great postwar project, the elegant and daring huge central Agnelli Hall (Hall B) of the Turin Exhibition Complex (1948): an extremely innovative building, shaped like a cathedral with a wide nave and an apse, conceived to host principally the automobile shows in the capital of the car making industry in Italy. For this extraordinary piece of art, he used precast ferrocement undulated elements for the hall's magnificent, transparent, 94 m (308 ft) span barrel vault. Diamond shaped ferrocement tiles with cast-in-situ interconnecting ribs were used for the dazzling pattern of the apse stylish network.

After this application, Nervi made an extensive and innovative use of ferrocement in a large number of his most daring and fascinating subsequent projects: ferrocement, combined with prefabrication, was the basic construction technique in these projects. He is thus credited as the reinventor of this technique.

ICJ: Can you describe some of these projects making use of ferrocement?

Professor Chiorino: Ferrocement can be used to mold prefabricated elements of any geometric shape, and the elements can then be connected by cast-in-place concrete. Like in the case of the Hall B of Turin Exhibition Complex, these elements can be undulated—as in the main vault of the Hall—or they can be shaped like tiles of various geometric forms, arranged side-by side and serving as incorporated formwork for cast-in-place concrete on their upper surfaces and within the contact channels at their edges to form structural reinforced concrete ribs—as in the apse of the same Hall.

The undulating elements were to be used by Nervi also in the great ribbed spherical cap dome, with a diameter of almost 100 m (328 ft), of the large Sports Palace built in 1960 for the Olympic Games in Rome—at the time the largest reinforced concrete dome the world over. In this case, different from the Hall B in Turin, the shapes and dimensions of the ferrocement elements vary along each on of the converging undulated ribs of the dome.

The use of the ferrocement tiles as incorporated formork elements was extensively adopted for the first time for a salt deposit in Tortona in 1949, and, especially, for the 55 x 157 m splendid dome of the additional Hall C for the Turin Exhibition Complex, designed and built by Nervi in 1950. In this case, the precast ferrocement elements are in the form of 20 mm thick, diamond-shaped tiles. The result is an extremely elegant impressive spatial mesh of reinforced intersecting ribs recalling the texture of the first series of hangars at Orvieto.

A similar pattern characterizes the structural fabric of the vaults and domes of some of Nervi's most famous later works: the Kursaal at Ostia (1950); the Ballroom at the Chianciano Spa (1952); the small Sports Palace in Rome (1957, with Antonio Vitellozzi) and in some significant works in USA: the Leverone Field House and Thompson Arena at Dartmouth College in Hanover, NH (1962, with Campbell and Aldrich, and 1976); the Norfolk Scope Arena in Norfolk, VA (1965-71, with Williams and Tazewell & Associates)—once again the largest dome in the world at the time, with a diameter of 135 m (443 ft); and St. Mary's Cathedral in San Francisco, CA (1963-71, with Pietro Belluschi). In this last famous iconic work, the ferrocement tiles and the mesh of concrete ribs adapt to the hyperbolic paraboloid surfaces of the high elegant dome marking the city's skyline. In the Gatti Wool Mill (Rome, Italy, 1951), the precast tiles are used to build a flat floor. In this case, the design of the rib pattern of the ceiling is derived from the lines of the principal bending moments, again resulting in a particularly refined formal effect that is found in a number of Nervi's subsequent projects.

ICJ: How would you describe Nervi's other constructions?

Professor Chiorino: In Italy, the most celebrated works of his maturity period and not in ferreocement include: the 135 m (443 ft) tall Pirelli Tower in Milan (1955-59), with Arturo Danusso and Gio Ponti); the facilities for the 1960 Rome Olympics, including, besides the two mentioned Sports Palaces, the Flaminio Stadium, and the Corso Francia Viaduct; the Palazzo del Lavoro in Turin (1961), built for the centennial celebrations of the Italian unification, with its geometrically fascinating columns featuring striped slanting surfaces covered by a steel umbrella-like structure (designed by Gino Covre); the Ponte Risorgimento in Verona (1963-68); and the Papal Audience Hall in the Vatican (1963-71, with Antonio Nervi). The latter project, a kind of apotheosis of his design and construction criteria and styles, recalls the themes of the Turin Exhibition Hall (from 20 years earlier), while enhancing them to create an imposing composition characterized by the spectacular convergence of the main undulated ribs of the vault toward the proscenium of the trapeizoidally shaped hall, and by the stunning sculptural shapes of the slanted main supporting columns with hyperbolic parabolid surfaces, and of the ribbed ceilings of the proscenium itself shaped once again according to the isostatics of bending moments.

ICJ: From the many examples, it appears that Nervi was very successful in his own country. Please describe some of his landmark structures outside Italy.

Professor Chiorino: Nervi's first important work outside Italy was the UNESCO Headquarters in Paris, France (1953-58, in cooperation with Marcel Breuer and Bernard Zehrfuss). The signature feature of this building is the fascinating folded structure of the exposed concrete of the walls and roof. A series of other prestigious commissions followed. Besides those mentioned previously in USA, the list includes: George Washington Bridge Bus Terminal in New York, NY (1962); Montreal's Victoria Square Tower, Canada (1961-66, with Luigi Moretti)—at the time, the tallest reinforced concrete building in the world at 145 m (475 ft); Australia Square and MLC Center Towers in Sydney (1964-72, with H. Seidler); the hyperbolic paraboloid umbrella roofs for Newark International Airport, NJ (1971); the B.I.T. headquarters building in Geneva, Switzerland (1972); and the Italian Embassy in Brasilia, Brazil (1979).

ICJ: Clearly, Nervi did not hesitate to try out many innovative design and construction ideas that could have been fraught with practical impossibilities. Was his pursuit for freedom in design, which in those times was confined by the lack of modern computerized structural analyses, also the principal justification for his keen interest in experimental research on mechanical scale models?

Professor Chiorino: The hangars he designed and built before World War II were the first structures for which, in addition to static calculations, Nervi relied on tests on reduced-scale models. The tests were performed by Professor Guido Oberti (1907-2004) at the Politecnico di Milano (Milan Institute of Technology), Italy, in the Model and Construction Testing Laboratory created by Arturo Danusso (1880-1968), using celluloid elastic models on a 1:30 scale. Nervi would maintain this procedure for most of his later works.

Nervi and Oberti considered experimentation to be the best strategy to overcome the practical impossibility, at that time, of basing safety checks of complex constructions on adequately accurate and computationally feasible theoretical models. A strategy also followed by other leading protagonists of structural architecture in the central years of 20th century, like Torroja, Dischinger, Tedesko, Hossdorf, to name a few.

It's fair to say that experimentation using models became itself an extremely refined art form, and an essential phase of the design path for Nervi and these other protagonists.

In fact, creating physical models required, almost in the same way as in real design and construction, the ability to combine technological expertise and imagination. The scientific collaboration between Nervi and Oberti, continued after 1950 within the new research laboratory of Istituto Sperimentale Modelli E Strutture (ISMES), founded by Danusso in Bergamo, Italy with the support of Italcementi, the leading Italian cement corporation. A laboratory specifically conceived for testing models of large dams and civil structures, which quickly reached international fame. One of the most complex models produced and tested within ISMES facilities was that of the reinforced concrete frame of the Pirelli Tower in Milan, Italy, (modeled in 1955-56). The nearly 10 m (33 ft) tall, 1:15-scale model (one of the largest scale models ever created for a building) was produced in micro-concrete of pumice stone and Portland cement and tested beyond service conditions up to failure, after a series of tests in the dynamic field to check the effects of wind. Other ISMES significant testing programs included the model of the Victoria Tower in Montreal, QC, Canada tested only in the elastic domain, and, especially, the wide series of models of St. Mary's Cathedral in San Francisco, CA. In this last case, a small scale (1:100) model was used for the wind tunnel tests, two medium-scale (1:40 and 1:37) resin models were used for static and dynamic tests in the elastic field (with special attention to seismic tests due to the building's location), and a large-scale (1:15) model constructed in micro-concrete for tests up to failure.

It's of interest to note that the elastic tests for St. Mary's were accompanied by checks—made by the U.S. engineering studio of Leonard Robinson, the local firm responsible for the final design—using numerical models based on early applications of elastic finite elements analysis computational approaches developed in those years at the University of California by the school of Alexander Scordelis. St. Mary's design marks in a certain sense the turning point from the extremely refined art of experimental reliability assessments to numerical analyses. Nervi's concrete towers in Sydney were tested in Australian laboratories and were the only two structures for which model testing was performed outside of ISMES.

ICJ: Tell us something about Nervi's book "Is building a Science or an Art?", and more in general on his approach to design that became for him a real form of art.

Professor Chiorino: Nervi's most famous book was published in 1945. Its title—*Scienza o Arte del costruire? (Is Building a Science or an Art?*)—represents the fundamental question debated in the book. In synthesis we may say that Nervi's answer to the question emphasizes the priority of the intuitive moment on the conception of structural architecture, yet it does so without underestimating the importance of the mechanics of structural systems: *"The conception of a structural system is a creative action only partly based on scientific data; static sensitivity entering in this process, although deriving from equilibrium and strength considerations, remains, in the same way as aesthetic sensitivity, an essentially personal aptitude."*

His vision was shared by Eduardo Torroja, the other great master of structural architecture of the 20th century, who declared in *"Razón y Ser de los Tipos Estructurales (Philosophy of Structures*, 1957)" that, *"the birth of a structural complex, the result of a creative process, the fusion of art and science, talent and research, imagination and sensibility, goes beyond the realm of pure logic to cross the arcane frontiers of inspiration."*

In this vision, Nervi essentially expresses his fear that forced requirements to use analytical models for reliability assessments of structures might limit a designer's inventiveness. In fact, he believed that structural imagination frequently transcended the possibilities of analytically rigorous verification, limited at the time, as we have underlined, by the lack of the modern computational tools. This struggle for a design freedom was also the principal justification for his keen just described interest for experimental research on models. It is interesting to note that Nervi was profoundly impressed by the fact that the numerical checks performed in US on St. Mary's dome essentially confirmed the experimental findings. However, to underline his imagination capacities, we must note that both assessment techniques essentially confirmed his original structural conception, indicating the need for just a few minor adaptations. A consideration that should be further discussed today, in an era where the form-finding processes are beginning to be delegated to the computational algorithms.

Nervi's extensive and interesting writings focus on the language of architecture and the relationship between structure and form, and on the ethical value of building in a correct manner. These were also the typical themes of the university teaching he regularly carried out at Rome's School of Architecture and of some of his important speeches and lectures at prestigious universities from Buenos Aires (1951) to Harvard, where he was nominated Charles Eliot Norton Professor of Poetry (Norton Lectures, 1961-62). They also characterized his exchanges of ideas and professional collaboration with those who shared his culture and mindset, such as Mario Salvadori, Structural Engineer and Professor at Columbia University.

ICJ: How did you conclude your keynote lecture on the work of Pier Luigi Nervi at the ACI Spring 2012 Convention in Dallas, Texas?

Professor Chiorino: The lecture was concluded by a brief description of the mission and scopes of the International Traveling Exhibition *"Pier Luigi Nervi: Architecture as Challenge"*, co-sponsored by ACI in recognition of Nervi's ACI Honorary Membership awarded in 1969. The Exhibition, which is presently touring Europe, is expected to tour North America and other continents in 2013-2015 (see box).

ICJ: Are any other celebrations of Nervi foreseen in the near future?

Professor Chiorino: Next year will mark the fiftieth anniversary of Nervi's 1963 Honorary Membership in IASS, the International Association for Shell and Spatial Structures, founded by Eduardo Torroja in 1959, of which Nervi was one of the cofounding and early active members. Nervi will be celebrated at the 2013 IASS Annual Symposium to be held in Wroclaw, Poland, on September 23-27, 2013, with a Special Session entitled *Pier Luigi Nervi – Art And Technology In Building* and with the dedication of a special issue of the *Journal of the IASS* . Both initiatives will explore, after half a century, the many facets of Nervi's personality of conceptor and designer of magnificent shell and spatial structures, in the light of modern approaches to structural architecture and form finding processes.

A photo feature on the work of Pier Luigi Nervi appears on pages 24 and 25

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The International exhibition:
"Pier Luigi Nervi – Architecture as Challenge".

The Exhibition is based on a broad research-educational program on Nervi's life and work started in 2009, on the occasion of the 30th anniversary of Nervi's death. The work was promoted by the Pier Luigi Nervi Project Association (PLN), the foundation based in Brussels and chaired by Nervi's grand-son Dr. Marco Nervi, devoted to the dissemination of Nervi's cultural legacy. The program has the scientific support of the Politecnico di Torino, the University of Rome, and La Cambre-Horta School of Architecture of the University of Brussels. The exhibition was organized by PLN and the Centre International pour la Ville et l'Architecture (CIVA), Brussels, in cooperation with the Italian National Museum of the Arts of the 21st Century in Rome (MAXXI) and the Study Center and Communication Archive (CSAC) of the University of Parma, Italy, under the auspices of the President of the Italian Republic and of other prominent institutions, including the Vatican City, the European Community, and the International Olympic Committee. ACI co-sponsored the exhibition in recognition of the ACI Honorary Membership awarded to Nervi in 1969 and in consideration of the significant number of his celebrated works in North America. Accompanied by a catalog—edited by architectural historian curators Carlo Olmo and Cristiana Chiorino and published by Silvana Editoriale (www.silvanaeditoriale.it; enter: Nervi)—which assembles the results of the research program, the exhibition started its extremely successful tour in Brussels, Belgium, in 2010.

The subsequent venues in Italy included the Venice Biennale of Architecture, the MAXXI, and the Turin Exhibition Hall—a building designed by Nervi himself. The Exhibition was recently presented in Copenhagen at the Danish Academy of Arts School of Architecture, Design and Conservation. After visiting other venues in Italy, Germany, Switzerland, and other European sites, it is expected to visit venues in North America and other continents in 2013-2015. On this occasion, the reprint by PLN of the Charles Eliot Norton Lectures given by Nervi at Harvard in 1961 will be available.

For more information about this travelling exhibition, please contact:
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