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Leonardo Ricci (1918-1994) Archives I

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Cover picture:

Leonardo Ricci at work during the setting of the" Costume Section" for the Italian Pavilion of the Montréal Exhibition of 1967, Casa Studio Ricci.

In credit page:

Leonardo Ricci, Montréal, 1967, Casa Studio Ricci.

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Mercato dei Fiori in Pescia (1948-1951): Design Inventiveness and Constructional Experimentation in Italy after the Second World War

Leonardo Ricci, Mercato dei Fiori in Pescia, Reinforced Brick, SAP-Self-Supporting Vaults, Architecture and Constructive Experimentation in Italy

/Abstract

After the Second World War, Italy shifted within a few years from post-war reconstruction to the economic "boom", attracting international attention with a series of highly original works and extraordinary examples of structural and constructional experimentation despite a strong technological delay compared to other industrialised countries.

In the immediate aftermath of the war, projects in which formal invention was closely linked to innovation in materials and structures developed all over Italy, creating a "built catalogue" of experimental techniques. Brick was among the materials that were widely available and deeply rooted in the traditional building. Indeed, the development of the so-called "reinforced brick" in the interwar period had paved the way to the construction of thin, light structures that could be built saving time and costs.

One of the first and most significant Italian experiments with this material was the *Mercato dei Fiori* (Flowers Market) in Pescia, Tuscany. It was the work of a team composed of architects Giuseppe Giorgio Gori, Leonardo Ricci, Leonardo Savioli, and Enzo Gori, along with the engineer Emilio Brizzi. The presence of four architects and one engineer in the group meant that the two aspects of the project – design and construction – were both thoroughly studied and intimately connected. This was the key to the successful combination of structural boldness and formal originality that made this building a case study in post-war Italian architecture and also earned it international fame. This structure still remains an important testimony to a formidable period of constructional experimentation in post-war Italy; the analyses of its material and structural aspects, which have not been considered so far by scholarly studies on either the building or its authors, represent fundamental investigative tools for fully understanding its value and innovation.

The paper proposes an analysis of the Market's space and compositional principles relying upon a deep understanding of its structural conception, since the simplicity and lightness of the final result were only possible thanks to the innovative adoption of technological solutions that were widely known but still used infrequently or in different settings.

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A perfect combination of architecture and engineering

After the Second World War, Italy shifted within a few years from post-war reconstruction to the economic "boom", attracting international attention with a series of highly original works and extraordinary examples of structural and constructional experimentation despite a strong technological delay compared to other industrialised countries.

In the immediate aftermath of the war, projects in which formal invention was closely linked to innovation in materials and structures developed all over Italy, creating a "built catalogue" of experimental techniques.

This paradox cannot be explained only by the talent of some brilliant professionals such as Pier Luigi Nervi (1891-1979), who first enjoyed celebrity status as a structural engineer in Italy at the end of 1930s and then worldwide following the architectural success of his buildings for the Rome Olympics in 1960[1].

Taking a step back, the post-war "Made in Italy" blend of architecture and engineering was the culmination of a long process of constructional experimentation, which began with the advent of reinforced concrete at the beginning of the century and continued during the so-called "autarchy" period (the "self-sufficiency" policy encouraged by the fascist regime from 1936, following sanctions levied by the League of Nations after the invasion of Ethiopia), until the 1940s and 1950s.[2] Under these autarchic policies, Italian builders had little access to steel. While the country had almost no iron or coal resources of its own and under the embargoes it could import only limited amounts of these materials.

These policies caused shortages of some raw materials. Therefore, top priority was given to making the most of the materials available and minimising complexities. Furthermore, the organisation of construction sites in Italy was still "artisanal" and strongly related to traditional methods and techniques. This confluence of construction economics, material scarcity, inspired design and politics was among the key factors that led to: a larger use of materials easily available in Italy, alone or combined together; the development of high-efficiency structural forms such as shells, vaults, membranes and surfaces; the improvement of construction systems targeted at minimising the use of scaffolding and centerings and at promoting the use of prefabrication processes, even in complex structures.

Brick was among the materials that were widely available and deeply rooted

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1 The most recent monographies on Pier Luigi Nervi's work are: Micaela Antonucci, Annalisa Trentin, and Tomaso Trombetti (eds.), *Pier Luigi Nervi. Architetture per lo sport / Pier Luigi Nervi's Sports Facilities, exhibition catalogue MAXXI – Museo delle Arti del XXI secolo di Roma, February 5-October 23, 2016* (Rome: MAXXI, 2016); Roberto Gargiani and Alberto Bologna, *The Rethoric of Pier Luigi Nervi. Concrete and Ferrocement Forms* (Lausanne: EPFL Press, 2016); Thomas Leslie, *Beauty's Rigor. Patterns of Production in the Work of Pier Luigi Nervi* (Urbana: University of Illinois Press, 2017); Micaela Antonucci and Gabriele Neri, *Pier Luigi Nervi in Africa. Evoluzione e dissoluzione dello Studio Nervi (1964-1980)* (Macerata: Quodlibet, 2021).

2 For more on these complex issues, simply mentioned here, see: Sergio Poretti, *Modernismi italiani. Architettura e costruzione nel Novecento* (Rome: Gangemi, 2008); Sergio Poretti, Pier Giovanni Bardelli, Antonio Cottone, Franco Nuti, Antonello Sanna (eds.), *La costruzione dell'architettura. Temi e opere del dopoguerra italiano* (Gangemi: Rome 2009); Paolo Desideri, Alessandro De Magistris, Carlo Olmo, Marco Pogacnik, Stefano Sorace (eds.), *La concezione strutturale. Ingegneria e architettura in Italia negli anni Cinquanta e Sessanta* (Turin: Umberto Allemandi & C., 2013).

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in the traditional building. Indeed, the development of the so-called "reinforced brick" in the interwar period had paved the way to the construction of thin, light structures that could be built saving time and costs. Since the 1930s, the "autarchy" policies promoted by the fascist regime had pushed the use of brick blocks in floor slabs and vaulted structures, in order to cover large spaces free from intermediate supports, thus reducing costs for reinforcement and scaffolding. This research produced exceptional results both in Italy and abroad in the post-war years – among the notable experiences are those of Eladio Dieste in Uruguay, Ildefonso Sánchez del Río in Spain and Guillermo González Zuleta in Colombia.[3]

One of the first and most significant Italian experiments with this material was the *Mercato dei Fiori* (Flower Market) in Pescia, Tuscany. It is the work of a team composed of architects Giuseppe Giorgio Gori, Leonardo Ricci, Leonardo Savioli, and Enzo Gori, along with the engineer Emilio Brizzi. It was the winner of a competition announced in 1948 by the municipal administration with the project having the motto "Quadrifoglio" (four-leaf clover).[4]

The project focused on the idea of a large free space, open on the sides to

3 For more recent references to these topics see: "Architettura Latino Americana," *Costruire in Laterizio*, 95 (2003); David López López, Théo Van Mele and Philippe Block, "Dieste, González Zuleta and Sánchez del Río: Three approaches to reinforced-brick shell structures," in Koel Van Balen and Els Verstrynge (eds), *Structural Analysis of Historical Constructions – Anamnesis, diagnosis, therapy, controls* (London: Taylor & Francis Group, 2016): 571-578; Adolfo F. L. Baratta, Antonio Magarò, "Volte funicolari sottili in laterizio: storia e sperimentazioni contemporanee," *Costruire in Laterizio*, 173 (2017): 72-79.

4 Among the most recent writings on this topic, see: Amedeo Belluzzi, Claudia Conforti, *Architettura italiana 1944-1985* (Rome-Bari, Laterza, 1985), 121-130; Caterina Cardamone, "Il Mercato dei fiori a Pescia," *La Nuova Città*, 5-6, (1999): 85-91; Corinna Vasić Vatovec, *Leonardo Ricci: architetto «esistenzialista»* (Florence: Edifir, 2005): 24-25; Claudia Massi (ed.), *Mercati dei Fiori di Pescia, exhibition catalogue* (Pescia, 1-31 June 2017) (Pisa: ETS, 2017); Alice Fantoni, "Architettura e sperimentazione costruttiva in Italia nel secondo dopoguerra: il Mercato dei Fiori di Pescia" (Single-cycle master's thesis in Building Engineering-Architecture, University of Bologna, academic year 2018-2019, lecturer Professor M. Antonucci); Mauro Cozzi and Ulisse Tramonti (eds), *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica* (Florence: ETS, 2020); Maria Clara Ghia, *La nostra città è tutta la terra. Leonardo Ricci architetto* (1918-1994) (Steinhauser Verlag: Wuppertal, 2021): 57-59.

Fig. 1

G. G. Gori, E. Gori, L. Ricci, L. Savioli, E. Brizzi, *Mercato dei Fiori*, Pescia, 1951 (Photo Barsotti, Florence. Fondo Gori, Biblioteca di Scienze Tecnologiche – Architettura, University of Florence).

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allow a close physical and visual relationship with the surrounding landscape, and covered by a large reinforced brick vault resting on sloping reinforced concrete walls [Fig. 1]. The members of the team had been working together since the mid-1940s: G. Gori, Ricci and Savioli, all three students and collaborators of the "maestro" Giovanni Michelucci, had already won various architectural tenders in Florence and in Tuscany in the immediate post-war period, in collaboration with both E. Gori and Brizzi and with other professionals.[5] The *Mercato dei Fiori* represented both the top result and the end of the collaboration between the five young Tuscan professionals, who from this moment on would take different paths.

The presence of four architects and one engineer in the group meant that the two aspects of the project – design and construction – were both thoroughly studied and intimately connected. This was the key to the successful combination of structural boldness and formal originality that made this building a case study in post-war Italian architecture and also earned it international fame after its huge success at the 1954 Biennale of Architecture of São Paulo in Brazil. This "multi-authorship" is the reason why still today scholars do not agree on the roles of each team member in the design concept and in the construction.

In her 2005 monograph on Leonardo Ricci, Corinna Vasić Vatovec wrote that Flora Wiechmann, wife of Leonardo Savioli, "attributed to Ricci the invention of the key theme of the vault, conceived as a large tent".[6] Several clues support this hypothesis: the fact that Savioli participated in the competition but did not sign the project documents nor the construction drawings[7]; the similarities between

5 Corinna Vasić Vatovec, "Leonardo Ricci nella stagione dell'esordio: dai concorsi fiorentini per la Ricostruzione al Mercato dei Fiori di Pescia," in Cozzi and Tramonti, *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica*, 126-151.

6 Vasić Vatovec, "Leonardo Ricci: architetto 'esistenzialista'," 25, footnote n. 41.

7 Claudia Massi, "Giuseppe Giorgio Gori architetto a Pescia: opere pubbliche, private, collaborazioni," in Cozzi and Tramonti, *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica*, 52-72: 60.

Fig. 2

Left: L. Ricci, Waldesian Village, Agape (1947-51); right: Mercato dei Fiori, Pescia: storages (1948-51).

the project for the market and the works of Ricci in the late 1940s and the early 1950s (the theme of "flying" architecture, as in Casa Balmain; the use of local stone and of the "scarp wall", as in the village of Agape and in Monterinaldi houses) [Fig. 2].

If the project idea was therefore probably attributable to Ricci with the contribution of Savioli, the construction of the work is undoubtedly attributable to the two Goris together with Emilio Brizzi, authors of the detailed design and working drawings. The two Gori architects – who shared a surname but were not relatives – played a decisive role in the modification and refinement of the original project, following the comments and requests of the competition committee. The engineer Brizzi proved key in defining the structural form, yet his contribution was generally ignored by critics.[8]

Mercato dei Fiori: forms, structures, materials

The Mercato dei Fiori is the result of the perfect combination of different contributions and of a precise match between formal will and constructional needs: each part and every detail have a both functional and aesthetic roles.

The result is a structure in which the space is shaped through a close interrelation between design and structural experimentation, responding to the logistical needs of a flower market but at the same time generating a neutral and extremely flexible space.[9]

An analysis of the Market's space and compositional principles must rely upon a deep understanding of its structural conception, since the simplicity and lightness of the final result were only possible thanks to the innovative adoption of technological solutions that were widely known but still used infrequently or in different settings.

The architectural complex is divided into four main parts: a large vault, two "squares" at the opposite ends on the shorter sides, and storage areas on the longer sides [Fig. 3].

The key element of the structure is the thin (only 15 cm thick), self-supporting, reinforced-brick vault that covers the central space, almost 24 m wide and 73 m long. The vault is supported by reinforced-concrete lateral buttresses, regularly spaced 14.40 m from each other, connected to the vault's springing point by reinforced-concrete, variable-section arches and triangular reinforced-concrete elements.

At the end of the 1940s in Italy the use of reinforced-brick vaults was not yet as widespread as it would become in subsequent decades (see the following

8 Francesco Lensi, Fabio Turcheschi, "Gli ingegneri di Giuseppe Giorgio Gori," in Cozzi and Tramonti, *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica*,114-124.

9 As the designers wrote in the 1949 General Report, "It was a question of designing a particular architectural complex that had to "work" perfectly like a machine, in all aspects (distributive, constructional, economic, etc.) and at the same time correspond in an equally perfect way to those artistic-environmental needs that the theme imposed" (*Mercati dei fiori a Pescia*: 141).

chapter). The choice of this technique for the construction of the *Mercato dei Fiori*'s vault therefore underscores the designers' ability to approach the technical and structural concept with an innovative, experimental attitude. The originality and the boldness of this project are also evident in the particular solutions adopted, which are clearly different from the ones currently used for "SAP"

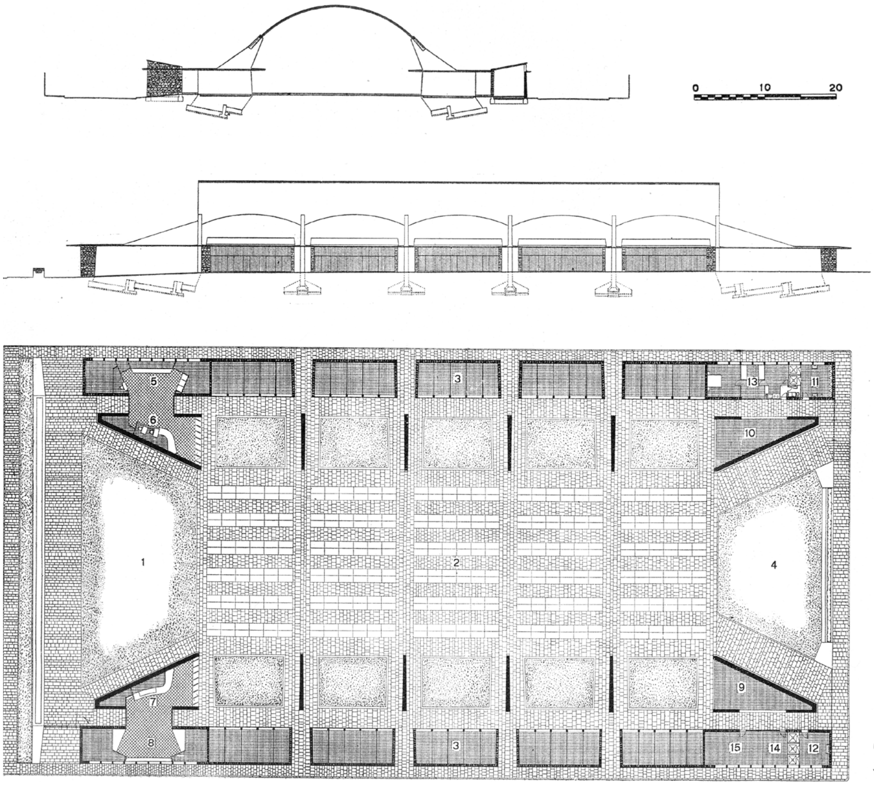

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Fig. 3

Mercato dei Fiori, Pescia: plan, side façade, section (source: *Casabella-continuità*, no. 209, 1956).

self-supporting, reinforced-brick vaults. For example, the thrust of the vault is opposed not by horizontal metallic chains but by inclined lateral buttresses, in order to leave the space under the intrados completely free.

The buttresses are elegant, thin reinforced-concrete walls, shaped according to the loads and thrusts of the vault. They assume a dual function, both static and architectural; not only do they take the dead weight of the roof, but they create two "squares" – the main entrance on the eastern side and the rear service entry on the western one – on the shorter sides and a sequence of "courtyards" that lead to storage areas on the longer sides.

The two "squares" have a dynamic trapezoidal shape, defined by the service buildings and by the diagonally inclined corner buttresses; they create a fluid continuity – both architectural and visual – between the inner and outer space.

The storage areas, structurally autonomous from the other parts of the complex, are along the longer sides of the central space and are organised into ten smaller rectangular boxes. In front of each box there were supposed to be small green areas with flowerbeds – but these were never built – which would have created a filter between the inner space under the vault and the lateral paths towards the storages.

In addition to these design and constructional innovations, one of the peculiar elements of this structure is the choice and the use of building materials, which – while having to comply with the limits imposed by the 1948 competition – give a precise identity to the various parts and define the structural elements. The brick vault is painted white, in order to create a sharp contrast with the blue of the sky visible from the inside. The exposed concrete buttresses and canopies are shaped with planed and oiled formwork. The storages walls are made of limestone from the quarries of Maona, near Montecatini Terme **[Fig. 4]**. The metallic elements, such as gates and windows, are painted light green. The flooring is made of local grey stone slabs, with the exception of the space under the vault, which consists of asphalt tiles.

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Fig. 4

Mercato dei Fiori, Pescia. Top: detail of the vault intrados; center: detail of the reinforced-concrete lateral buttresses supporting the vault; bottom: detail of the walls of the storages, made of limestone from the Maona quarries.

The use of these materials and the structural concept were considered a reference to Tuscan building tradition by scholars, starting with Ernesto Nathan Rogers who identified the market as "a whole that makes us think of Filippo Brunelleschi's succession of arches and vaults, statically logical and consistent yet materially light" (1956).[10] The idea of a "Tuscan heritage" was later repeated by other scholars, most recently by Corinna Vasić Vatovec, who linked the Mercato's vault to the Florentine Renaissance's groined vaults like those of Palazzo Gerini, well known to both Gori and Ricci (2020).[11] This supposed reference to the local building tradition was re-evalueted by Claudia Conforti and Amedeo Belluzzi, according to whom the Mercato has instead an "Apollonian structuralism, drained of all emphatic details" (1985).[12]

As for the construction processes employed, thanks to Giuseppe Giorgio Gori we have valuable testimony about the organisation of the construction site. In fact the Florentine architect made a scientific documentary for educational purposes that recorded the most important phases of the construction of the

10 Ernesto Nathan Rogers, "Il mercato dei fiori di Pescia degli architetti E. Brizzi, E. e G. Gori, L. Ricci, L. Savioli", *Casabella-continuità*, no. 209 (January-February 1956): 28-33.

11 Vasić Vatovec, "Leonardo Ricci nella stagione dell'esordio," 151.

12 Belluzzi and Conforti, *Architettura italiana 1944-1985*, 121.

Mercato dei Fiori. This is a fundamental document, since it allows us to know the construction methods and phases as well as providing an important aid in understanding the design of all the project details, since not all the construction drawings are available. The documentary shows the various building phases, from the foundation to the construction of the vault (which will be described in more detail in the following chapter), and the load tests performed on a celluloid model at Milan Polytechnic. The shots alternate with "educational" interludes where the project is illustrated by drawings and structural diagrams, including a presentation of the vault construction system and of support structures.[13]

Despite the positive reviews and the international fame it had gained, the original structure of the *Mercato dei Fiori* was soon modified and in some parts it was completely changed.

Just a few years after the building was completed, the exponential increase in the floriculture trade in Pescia and Valdinievole and the extension of the seasonality from the summer to the entire year due to increased use of greenhouses, soon made the spaces inadequate. In order to increase space, the lateral areas between the buttresses were covered with wattles and curtains and the arches at the base of the vault were closed, interrupting the spatial continuity between the inside and outside.

Brizzi and Giuseppe Giorgio Gori developed various proposals to expand the market by closing the rear trapezoidal square with a system of overhangs made of folded thin reinforced concrete slabs, supported by trestles consisting of diamonds staggered in the adjacent rows. It is interesting to note that once again, as with the original building, research related to technological and constructional innovation was at the centre of the project: the thickness of the overhangs (3 cm), which complemented the lightness of the central vault, was made possible by using a diffuse metallic reinforcement consisting of overlapping steel meshes, inspired by the ferrocement technique patented by Pier Luigi Nervi (a lightweight combination of metal mesh and aggregate-free cement that he had perfected in experimental constructions in 1940s) – as Brizzi himself explicitly stated in the report for the market expansion project.[14]

Despite the efforts made to adapt the original structure the added space still was not enough and therefore in 1970 a competition was announced to design a new flower market, to be built in a larger area near the station and the entrance of the motorway; the winner was the group led by Leonardo Savioli (one of the old market's designers) and Danilo Santi.[15] Emptied of its original functions, the old market slowly suffered an inexorable decline. The arches on the sides were closed, the courtyards were

13 "Il Mercato dei Fiori a Pescia" Cinedocumentario didattico 16 m/m, (Fondo Gori, serie 3. Biblioteca di Scienze Tecnologiche – Architettura, University of Florence). Filming began on 1 July 1950 and ended on 26 February 1951.

14 Emilio Brizzi, "Progetto di ampliamento del mercato dei fiori a Pescia (Impiego di elementi costruttivi prefabbricati)," in *Bollettino degli Ingegneri*, 7, 1966: 3.

15 Belluzzi and Conforti, *Architettura italiana 1944-1985*, 124-130.

obscured by sheet metal canopies supported by reticulated metal structures, and the materials deteriorated.[16]

Yet, this structure still remains an important testimony to a formidable period of constructional experimentation in post-war Italy; the analyses of its material and structural aspects, which have not been considered so far by scholarly studies on either the building or its authors, represent fundamental investigative tools for fully understanding its value and innovation.

Reinforced-brick structures in twentieth-century Italy

The great availability of raw materials in Italy for brick production has always made it an extremely cost-effective material, and thanks to both the wide assortment of solutions and combinations with other materials more and more new products were developed. In the early decades of the 20th century a variety of bricks shaped in different forms for the construction of single/double-frame ribbed floors were patented.

The combination of brick and steel enabled the construction of extremely light and thin structures, making the most of the physical properties of both materials. Patents for reinforced brick floors multiplied in a continuous effort to optimise both structural forms and construction methods, with options ranging from prefabrication to on-site construction.[17] Brick manufacturers offered a multitude of different solutions, yet all of them had similar characteristics and basic principles: a surprising variety, especially considering that validations of structural calculations relied only on static intuition and on experimental tests with prototypes and scale models.[18]

Despite general scepticism, thanks to the good results of the field-tests – confirming the similarity of the elastic modulus of brick and concrete and the excellent adhesion and the high compressive strength of brick – the Regio Decreto (royal decree) of 16 November 1939 enabled the construction of floors without topping slabs, provided that the bricks were shaped with adequate reinforcement in the upper part, exploiting the collaboration between brick, concrete and steel.

Among the most successful patents was that of the SAP self-supporting cement-block floor slabs and vaults, produced by Fornaci F.lli Rizzi, Donelli, Breviglieri e C. (RDB) in Piacenza, a firm that remained a leader in the Italian brick industry throughout the 20th century thanks to a considerable

16 On the subsequent transformations of the Market, reference is made to the reconstruction by Fantoni, "Architettura e sperimentazione costruttiva in Italia nel secondo dopoguerra," 24-33. On the decay of the architecture, see also Maurizio De Vita, "Considerazioni sul 'Restauro Del Moderno'. Il caso dell'ex Mercato dei Fiori di Pescia, " in Riccardo Lentile (ed.), *Architetture in Cemento Armato. Orientamenti per la conservazione* (Milan: Franco Angeli Editore, 2008), 171-177.

17 Giorgia Predari, *I solai latero-cementizi nella costruzione moderna in Italia, 1930-1950* (Bologna: Bononia University Press, 2015).

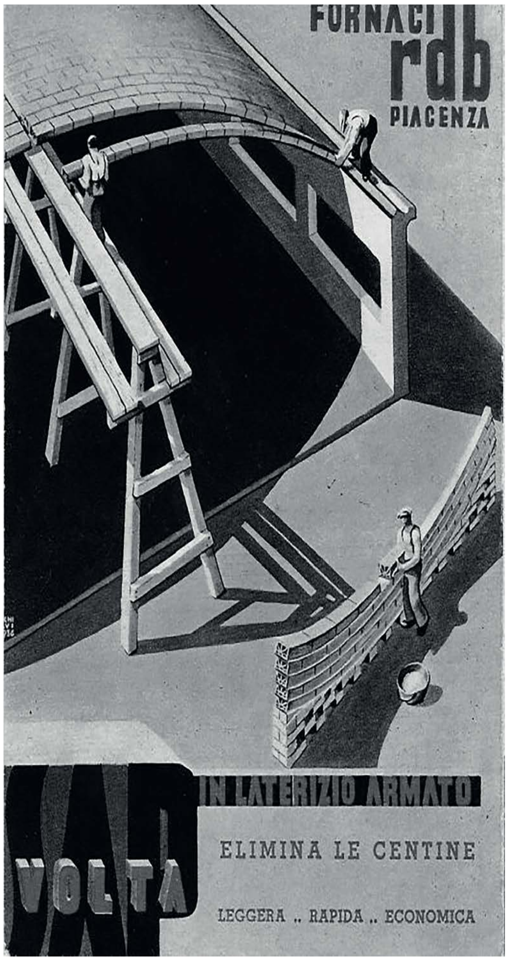
18 On the use of models in structural design in Italy after the war, see Gabriele Neri, *Capolavori in miniatura. Pier Luigi Nervi e la modellazione strutturale* (Mendrisio/Cinisello Balsamo: Mendrisio Academy Press/Silvana Editoriale, 2014).

entrepreneurial skill and the ability to collaborate with universities and professionals.[19]

RDB's first experiments dated back to the 1920s, seeking to give bricks a main static role: the Solaio Auto-Portante (SAP) ("self-supporting floor"), inspired by a similar English concrete product,[20] was the most significant result of this research **[Fig. 5]**. It soon was increasingly used in Italy, thanks to its main features: minimal use of steel, impressive lightness, no need for large scaffolding, and simple and quick construction processes. While other kilns produced similar brick blocks, RDB products remained the brand of choice throughout the last century.[21]

The drive for technological innovation was also conditioned by political and economic reasons. As aforementioned above, since the second half of the 1930s the adoption of autarchic policies by the Fascist regime limited the use of imported materials such as iron, coal and wood, harshly limiting the use of reinforced concrete and forcing producers and designers to find alternative construction methods and materials.

The need to cover large spaces without using metal or reinforced concrete structures while also limiting the use of scaffolding as much as possible, produced great efforts to find ways to use brick blocks to build shell and vaulted structures.[22]



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Vaults could be built with both "regular" blocks used for floor slabs and "special" blocks whose shapes were tuned to be used in prefabricated arches or in other built-on-site structures. Among the blocks produced by RDB, those most used (aside from the self-supporting SAPs) were the Sapals, used in some particular kind of vaults, the ST'AR for double-curved roofs and rotation domes, and Celersaps, used for hyperbolic paraboloid roofs.

Based on these inventions and experiments, in the decades following the Second World War reinforced-brick floors and vaults were used more and more in Italy, due to economic reasons but also because they could be tuned to fit different forms and needs. These structures were used to build industrial buildings, sports facilities, churches, warehouses, markets, canopies, and

19 Paolo Baldini and Gustavo Roccella, *C'era una volta: novant'anni di storia RDB* (Piacenza: Nuova Litoeffe, 1998).

20 The SAP beam system consisted of perforated base elements having a parallelepiped shape available in four heights, i.e. 8, 12, 16 and 20 cm, 20 cm wide and 20-30 cm long, which were assembled at the building site or in specialised workshops, combining them to form beams up to 6 m in length. The beams were placed by resting them at the ends and positioning them next to each other, filling the gaps with cement mortar.

21 Other companies proposed bricks of similar conception, such as the arch vault of the Morelli company of Ancona, the Est vault of the Frazzi kilns in Cremona and the Trirex panels of Fornaci Valdadige, but also having different characteristics, such as the Morelli lamellar vaults composed of parallelepiped perforated brick elements with an elongated shape having lateral grooves for the rebar, mounted to form a rhomboidal frame that could be completely covered or left visible.

22 In 1937 a large prototype of a SAP self-supporting vault was built in the experimental field of Pontenure, home of the RDB Testing Laboratory, with a net span of 40 m and a thickness of only 20 cm, on which symmetrical and dissymmetrical load tests were performed, first with horizontal thrust eliminated by elastic tie rods and then with thrust contained by special buttresses.

Fig. 5

Advertising of the SAP self-supporting cement-block floor slabs and vaults, produced by Fornaci F.lli Rizzi, Donelli, Breviglieri (RDB), 1936.

other situations requiring large, covered spaces. Reinforced-brick vaults were generally built using curvilinear prefabricated reinforced-brick beams measuring about 5 m long, made of the same blocks used for the SAP self-supporting floors. These curvilinear beams were composed of elementary blocks cast together by cement mortar longitudinally and by reinforced-concrete ribs (15 to 25 cm thick) laterally. Generally the vaults' sectional shapes took the forms of depressed arches, but they could also be shaped by mixed or pointed arches. The horizontal thrust loads at the vault's springing was balanced by special metal tie-rods equipped with threaded turnbuckles. Prefabricated blocks forming the vault could be produced on site or in specialised production sites. The curved sections of the vault were shaped using a movable wooden board with an edge shaped according to the required curvature.

To build these structures, trestles bearing narrow trusses were prepared to support the edges of the beams and to put the longitudinal ribs in place. If the length of the beams exceeded 3 m, it was necessary to insert intermediate crossbars. A crane lifted the beams from the ground to put them in place on the supports. Additional reinforcements were then put in place: metal chains, tie brackets between the longitudinal joists to ensure the continuity of the reinforcement and blocks to reinforce the vault's springing. After having generously wet the bricks and the formworks, casting operations began, starting from the springing and the wall beams and then moving to the longitudinal and intermediate ribs.

6

The vault of the *Mercato dei Fiori* in Pescia is a SAP reinforced-brick vault, yet here this technology is used in an innovative way to create original forms and bold static concepts. Thanks to the aforementioned documentary on the construction of the market filmed by Giuseppe Giorgio Gori, we can see that all construction methods employed to build the vault were not experimental or new. Rather, they were adapted to

Fig. 6

Frames of the scientific documentary recording the most important phases of the construction of the *Mercato dei Fiori* ("*Il Mercato dei Fiori a Pescia" Cinedocumentario didattico 16 m/m*. Fondo Gori, serie 3. Biblioteca di Scienze Tecnologiche – Architettura, University of Florence).

build the innovative and bold solution imagined by Leonardo Ricci and the other designers. The result is an architecture where tradition is at the service of innovation [Fig. 6].

Mercato dei Fiori: technical and structural concept

The vault of the Mercato dei Fiori is formed by depressed circular-shaped arches, each of whom is composed of five elements made of curved SAP-self-supporting square beams, measuring 20 cm a side and about 4.50 m long.

These elements are connected longitudinally by six reinforced-concrete wall ribs, measuring 20 cm a side; additionally, tie brackets are inserted between the beams in order to become structurally integral [Fig. 7].

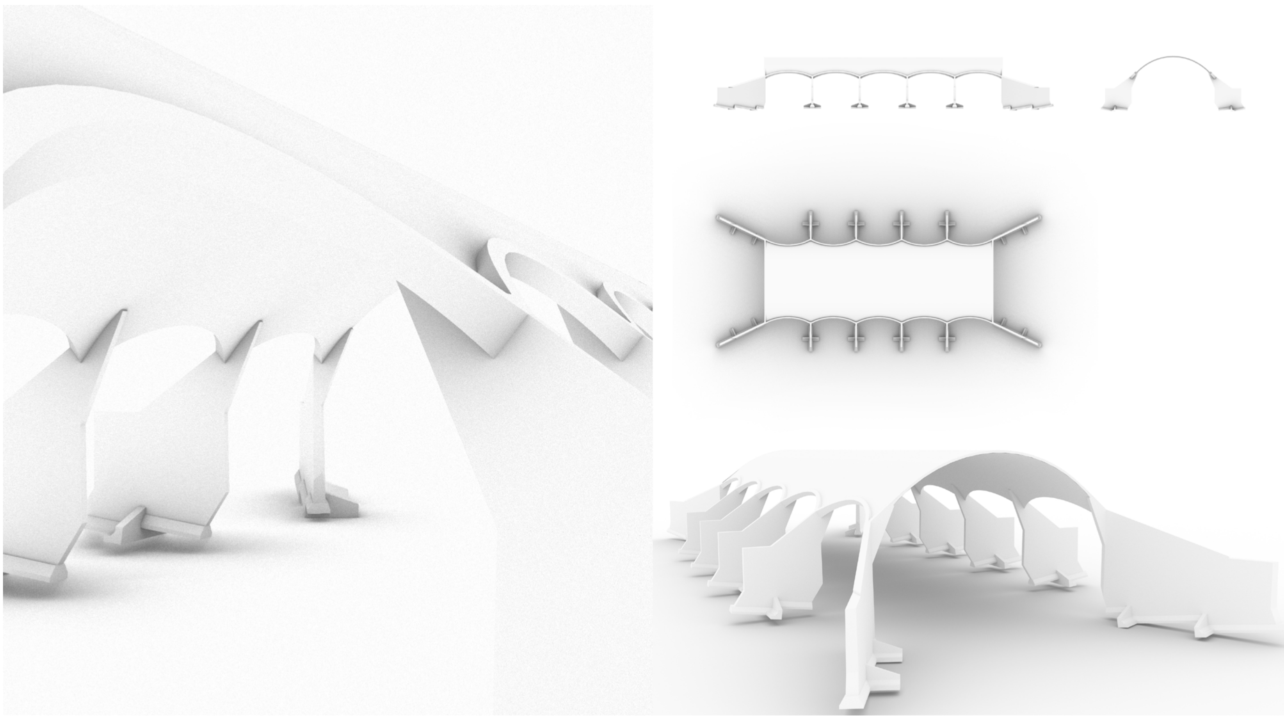
The vaults' spring from reinforced-concrete arches with variable sectional shapes, connected to the lateral buttresses by reinforced-concrete triangular elements, 20 to 35 cm thick and lightened by alternating rows of bricks. The arches, placed on an inclined plane, intersect the vaults' surfaces, helping to convey the thrust loads to the lateral buttresses; their dimensions vary between 50 cm at the keystone to 80 cm on the springing in height, measuring 40 cm in thickness.

The brick-element sections of the vaults have a span of about 20.30 meters and a rise of 4 m. Considering the vault including the side arches, the span is about 23.50 meters, with a rise of 5.70 m. The total length of the vault is about 73 m.

The vault is supported by two pairs of reinforced-concrete corner buttresses and four pairs of reinforced-concrete lateral buttresses, 40 to 65 cm thick, spaced 14.45 meters apart. Their upper part is tilted following the resulting thrust lines

Fig. 7

Mercato dei Fiori, Pescia: structural 3D model of the vault (author: Alice Fantoni).



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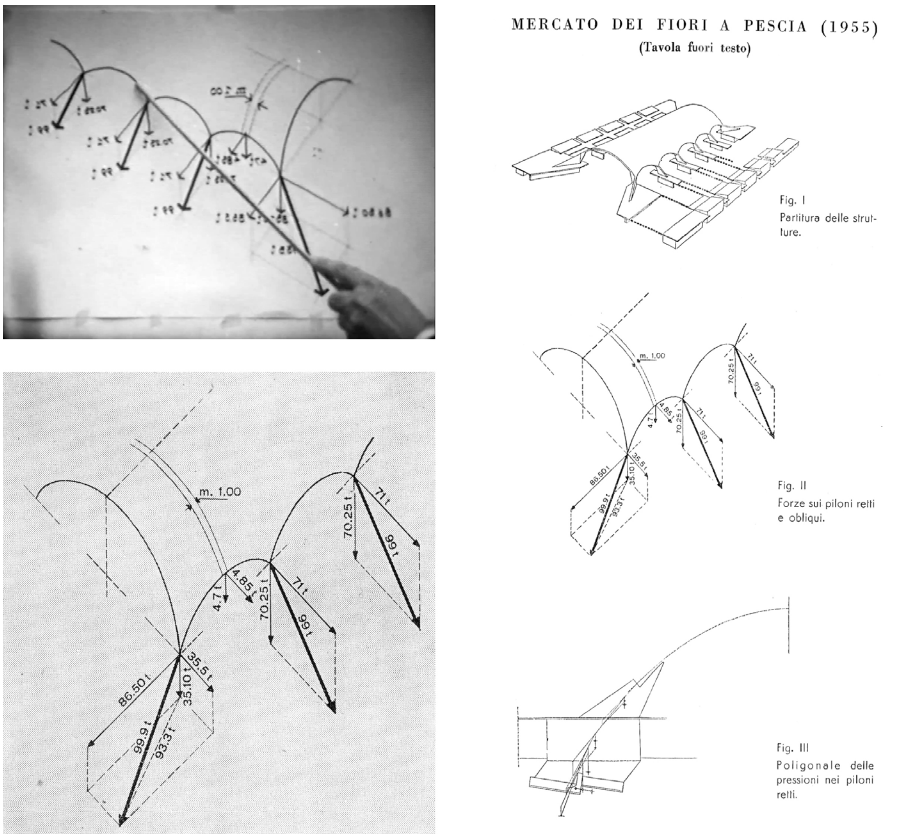

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of the vault. A thin concrete overhang covers the side spaces between the vaulted space and the storage boxes; it is grafted into the edge buttresses of the vault and structurally joined with the roof of the storage boxes.

There is no clear information about the building's foundation system, which consists of a widening at the base of the buttresses, inclined to better diffuse the loads into the ground and joined with elements perpendicular to the buttresses having a stabilising function.

The brick blocks used in the vault of the *Mercato dei Fiori* have similar characteristics to RDB's SAP bricks, but we have neither specific information on the manufacturer that produced them nor the original calculations or executive drawings. So, we have to carefully analyse every document available, from the drawings published in the article published by Ernesto Nathan Rogers in 1956 to the historical photos, from the documentary made by Gori to the first architectural drawings preserved in the Gori Collection in the Biblioteca di Scienze Tecnologiche – Architettura (Library of Technological Sciences - Architecture) of the University of Florence.[23]

One of the elements that can help us to understand what the designers' approach may have been is a diagram visualizing the vector composition of the vault's thrust loads on the side arches and from the latter on the buttresses. This diagram is included in the *General Report* drawn up by Brizzi, E. Gori, G. Gori and

23 The brick blocks used to build the vault of the Mercato dei Fiori measure 20 x 20 x 30 cm. While their dimensions are the same as the RDB's SAP 20, the design of the inner cavities and the arrangement of the reinforcements were different. Indeed, the arched structure of the internal cavities and the lower portion are similar to the ones of Cirex bricks produced by Fornaci Valdadige, which however had a slightly elongated form and a single extrados groove for the housing of a rod.

Fig. 8

Diagram visualizing the vector composition of the vault's thrust loads on the side arches and from the latter on the buttresses (sources, top left: frame of the 1951 documentary about the construction phases of the building; bottom left: image of the article published in *Casabella-continuità*, 209, 1956; right: image in the teaching manual *Statica Grafica e Analitica* published by Emilio Brizzi in 1959).

Ricci in 1949; it is also in the 1951 documentary about the construction phases of the building and was among the images of the article published by Ernesto Nathan Rogers in *Casabella* in 1956 and in the teaching manual Statica Grafica e Analitica published by Emilio Brizzi in 1959[24] [Fig. 8].

The diagram expresses the static principles within the vault and the buttresses, as a result of the calculations – although none of the aforementioned sources include calculations or comments describing the figure in detail.

Yet, this (apparently) simple illustration proves key to understanding the *Mercato dei Fiori*'s structural concept, providing us with useful information on the structural scheme and the simple calculations used.

When this project was conceived, theories for the design of thin vaults were well known: yet, the lack of practical tools to easily perform the structural calculations was still a major problem. Therefore, it was generally preferred to use simple models that, through specific adjustments, could provide a simulation of the structural behaviour as accurately as possible. In particularly complex or difficult situations, the theory of "limiting hypotheses" was used, adopting a "weighted average" method for calculating and dimensioning the structural elements.

In the case of the *Mercato dei Fiori*, as the analysis of the sources and documents shows, the vault was conceived by its designers as a flat hinged-arch structure with an even width and uniformly distributed loads.

Despite the fact that the triangular reinforced-concrete elements and the arches at the vault's springing have different, not easily quantifiable effects on its structural equilibrium, this scheme enabled the designers to make relatively simple calculations and helped achieve statically-valid forms and dimensions of the structural elements.

The recent structural analysis of the *Mercato dei Fiori*[25] was carried out by developing models of increasing complexity and using Finite Elements Analysis (FEA) software, which enabled us to overcome the difficulties involved in evaluating the non-isotropic behaviour of the reinforced brick. This analysis was paramount in investigating the choices made by the designers using the tools at their disposal in 1940s and the methodologies they used.

A model of the vault, including the connecting gables and side arches, was created, at first using beam elements and then plate elements. Finally an overall plate-elements model, including buttresses and foundations, was produced. Throughout this work, we have examined how differently these two schemes behaved in simulating each vault's structural behaviour, to understand the pros and cons that each method offered [Fig. 9].

The comparison of the modelling results enabled us to appreciate the

24 Emilio Brizzi, *Statica Grafica e Analitica, elasticità e resistenza materiali, le quattro sollecitazioni semplici* (Florence: Tip. A. Lumini, 1959).

25 Alice Fantoni, "Architettura e sperimentazione costruttiva in Italia nel secondo dopoguerra," 157-207.

designers' ability to understand the fundamentals of their structural behaviour despite the limited tools available of the time, using "static sensitivity" in the service of architectural design and modelling every part based on the static needs.

The Mercato dei Fiori is therefore an extraordinary example of the spirit of experimentation of post-war Italian architecture, in which formal and structural design perfectly match, creating a coherent and innovative building.

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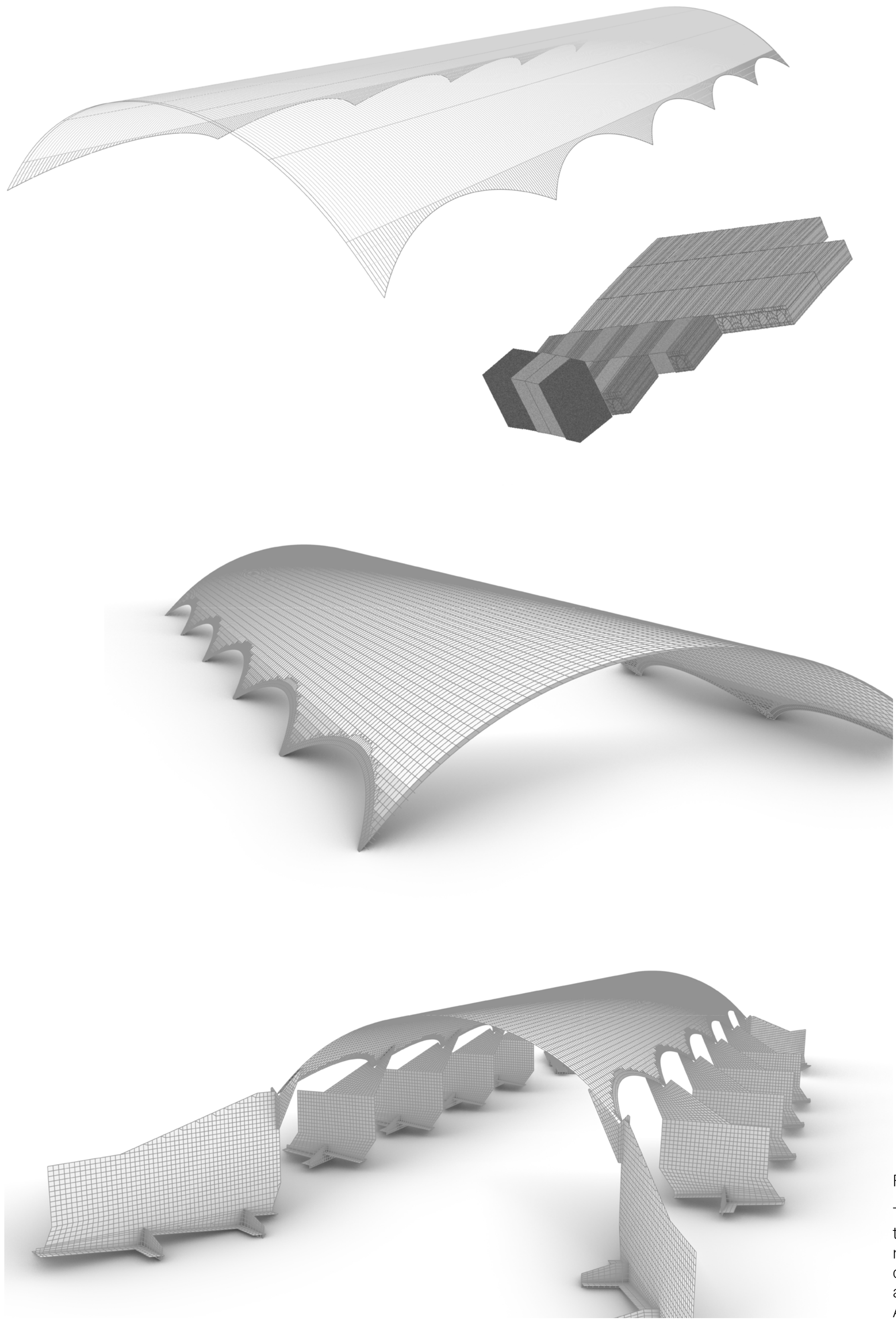

Fig. 9

Top to bottom: 3D models of the vault, including the connecting gables and side arches, created using beam elements and plate elements (author: Alice Fantoni).

Bibliography

"Architettura Latino Americana", *Costruire in Laterizio*, 95 (2003).

Antonucci, Micaela and Gabriele Neri. *Pier Luigi Nervi in Africa. Evoluzione e dissoluzione dello Studio Nervi (1964-1980).* Macerata: Quodlibet, 2021.

Antonucci, Micaela, Annalisa Trentin and Tomaso Trombetti, eds. *Pier Luigi Nervi. Architetture per lo sport / Pier Luigi Nervi's Sports Facilities*, exhibition catalogue (MAXXI – Museo delle Arti del XXI secolo di Roma, February 5-October 23, 2016). Rome: MAXXI, 2016.

Baldini, Paolo and Gustavo Roccella. *C'era una volta: novant'anni di storia RDB*. Piacenza: Nuova Litoeffe, 1998.

Baratta, Adolfo and Antonio Magarò. "Volte funicolari sottili in laterizio: storia e sperimentazioni contemporanee." *Costruire in Laterizio*, 173 (2017): 72-79.

Belluzzi, Amedeo and Claudia Conforti. *Architettura italiana 1944-1985*. Rome-Bari, Laterza, 1985.

Brizzi, Emilio. *Statica Grafica e Analitica, elasticità e resistenza materiali, le quattro sollecitazioni semplici*. Florence: Tip. A. Lumini, 1959.

Cardamone, Caterina. "Il Mercato dei fiori a Pescia." *La Nuova Città. Rivista fondata da Giovanni Michelucci*, 5-6 (1999): 85-91.

Cozzi, Mauro and Ulisse Tramonti, eds. *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica*. Florence: ETS, 2020

De Vita, Maurizio. "Considerazioni sul 'Restauro Del Moderno'. Il caso dell'ex Mercato dei Fiori di Pescia." In *Architetture in Cemento Armato. Orientamenti per la conservazione*, edited by Riccardo Ientile, 171-177. Milan: Franco Angeli Editore, 2008.

Desideri, Paolo, Alessandro De Magistris, Carlo Olmo, Marco Pogacnik, Stefano Sorace, eds. *La concezione strutturale. Ingegneria e architettura in Italia negli anni Cinquanta e Sessanta*. Turin: Umberto Allemandi & C., 2013.

Fantoni, Alice. "Architettura e sperimentazione costruttiva in Italia nel secondo dopoguerra: il Mercato dei Fiori di Pescia." Single-cycle master's thesis in Building Engineering-Architecture, University of Bologna, academic year 2018-2019, lecturer Professor M. Antonucci.

Gargiani, Roberto and Alberto Bologna. *The Rethoric of Pier Luigi Nervi. Concrete and Ferrocement Forms*. Lausanne: EPFL Press, 2016.

Ghia, Maria Clara. *La nostra città è tutta la terra. Leonardo Ricci architetto (1918-1994)*. Steinhauser Verlag: Wuppertal, 2021.

Lensi, Francesco and Fabio Turcheschi, "Gli ingegneri di Giuseppe Giorgio Gori." In *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica*, edited by Mauro Cozzi and Ulisse Tramonti. Florence: ETS, 2020, 114-124.

Leslie Thomas. *Beauty's Rigor. Patterns of Production in the Work of Pier Luigi Nervi*. Urbana: University of Illinois Press, 2017.

López López, David, Théo Van Mele and Philippe Block. "Dieste, González Zuleta and Sánchez del Río: Three approaches to reinforced-brick shell structures." In *Structural Analysis of Historical Constructions – Anamnesis, Diagnosis, Therapy, Controls*, edited by Koel Van Balen and Els Verstrynge, 571-578. London: Taylor & Francis Group, 2016.

Massi, Claudia, ed. *Mercati dei Fiori di Pescia*, exhibition catalogue (Pescia, 1-31 June 2017). Pisa: ETS, 2017.

Massi, Claudia. "Giuseppe Giorgio Gori architetto a Pescia: opere pubbliche, private, collaborazioni." In *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica*, edited by Mauro Cozzi and Ulisse Tramonti, 52-72. Florence: ETS, 2020.

Neri, Gabriele. *Capolavori in miniatura. Pier Luigi Nervi e la modellazione strutturale*. Mendrisio/Cinisello Balsamo: Mendrisio Academy Press/Silvana Editoriale, 2014.

Poretti, Sergio. *Modernismi italiani. Architettura e costruzione nel Novecento*. Rome: Gangemi, 2008.

Poretti, Sergio, Pier Giovanni Bardelli, Antonio Cottone, Franco Nuti, Antonello Sanna, eds. *La costruzione dell'architettura. Temi e opere del dopoguerra italiano*. Gangemi, Rome 2009.

Predari, Giorgia. *I solai latero-cementizi nella costruzione moderna in Italia, 1930-1950.* Bologna: Bononia University Press, 2015.

Rogers, Ernesto Nathan. "Il mercato dei fiori di Pescia degli architetti E. Brizzi, E. e G. Gori, L. Ricci, L. Savioli." *Casabella-continuità*, no. 209 (January-February 1956): 28-33.

Vasić Vatovec, Corinna. "Leonardo Ricci nella stagione dell'esordio: dai concorsi fiorentini per la Ricostruzione al Mercato dei Fiori di Pescia." In *Gli architetti del Mercato dei fiori di Pescia negli anni della ricostruzione postbellica*, edited by Mauro Cozzi and Ulisse Tramonti, 126-151.Florence: ETS, 2020.

Vasić Vatovec, Corinna. *Leonardo Ricci: architetto «esistenzialista»*. Florence: Edifir, 2005.